CORPS OF ENGINEERS, U. S. ARMY

# FLOOD-CONTROL PROJECT FOR NORTHWEST BRANCH, ANACOSTIA RIVER DISTRICT OF COLUMBIA AND MARYLAND

## HYDRAULIC MODEL INVESTIGATION

TECHNICAL REPORT NO. 2-434

CONDUCTED FOR

WASHINGTON DISTRICT, CORPS OF ENGINEERS

BY

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

ARMY-MRC VICKSBURG, MISS.

JUNE 1956

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



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|---|---|---|
| 1. REPORT DATE<br>**JUN 1956** | 2. REPORT TYPE | 3. DATES COVERED<br>**00-00-1956 to 00-00-1956** |
| 4. TITLE AND SUBTITLE<br>**Flood-control Project for Northwest Branch, Anacostia River, District of Columbia and Maryland: Hydraulic Model Investigation** | | 5a. CONTRACT NUMBER<br>5b. GRANT NUMBER<br>5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | | 5d. PROJECT NUMBER<br>5e. TASK NUMBER<br>5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**U.S. Army Corps of Engineers,Waterway Experiment Station,3903 Halls Ferry Road,Vicksburg,MS,39180** | | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSOR/MONITOR'S ACRONYM(S)<br>11. SPONSOR/MONITOR'S REPORT NUMBER(S) |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br>**Approved for public release; distribution unlimited** | | |
| 13. SUPPLEMENTARY NOTES | | |
| 14. ABSTRACT | | |
| 15. SUBJECT TERMS | | |

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a REPORT<br>**unclassified** | b ABSTRACT<br>**unclassified** | c THIS PAGE<br>**unclassified** | **Same as Report (SAR)** | **81** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

# PREFACE

A hydraulic model investigation of flood-control plans for the Anacostia River was authorized by the District Engineer, Washington District, CE, in an indorsement dated 30 December 1953. The study was conducted in the Hydraulics Division of the Waterways Experiment Station during the period January 1954 to January 1955 by Messrs. J. J. Franco, C. D. McKellar, Lloyd Woods, and A. J. Green.

During the course of the model study, close liaison was maintained between the Washington District and the Waterways Experiment Station, chiefly through monthly progress reports, special reports, and visits. Results of tests on the model were submitted to the District Engineer upon completion of each test. Messrs. Floyd Morris and H. E. Schwarz of the Washington District and Mr. B. H. Dodge of the North Atlantic Division visited the Experiment Station to observe the model in operation and to witness the preliminary testing of various improvement plans and modifications.

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# SUMMARY

A 1:30-scale model was used to study flood-control plans for a reach of the Northwest Branch of the Anacostia River near its junction with the Northeast Branch. Plans for this reach included the construction of a section of high-velocity concrete channel 550 ft long to pass flood waters safely through two existing bridges and preclude the need for their reconstruction. The reach in question is subject to tidal effects as well as backwater effects from the Northeast Branch. The purposes of the model study were to check the adequacy of the proposed improvement plan, which had been designed on the basis of hydraulic computations, and to develop such modifications as might be found desirable. The fixed-bed model reproduced the concrete channel with bridges and about 1600 ft of the channel and floodway upstream and downstream therefrom.

It was determined from the investigation that the proposed design would result in unstable flow below the Baltimore and Ohio Railroad bridge within the high-velocity channel, and that the hydraulic jump would not be retained on the paved section at the end of the high-velocity channel for all tailwater conditions. Satisfactory modifications developed during the model study included a decrease in the floodway width upstream of the paved channel, superelevation of the channel floor within the curve of the high-velocity channel, and changes in the alignment of side-wall transitions.

# FLOOD-CONTROL PROJECT FOR NORTHWEST BRANCH, ANACOSTIA RIVER
# DISTRICT OF COLUMBIA AND MARYLAND

## Hydraulic Model Investigation

## PART I: INTRODUCTION

### Location and Description of Prototype

1. The Anacostia River is formed by the junction of Northeast and Northwest Branches at Bladensburg, Maryland, about 2000 feet north of Bladensburg Road, and flows in a southwesterly direction for a distance of 9 miles to its confluence with the Potomac River in the locality of Fort McNair in Washington, D. C. (see fig. 1). The Northwest Branch of the Anacostia River rises near Sandy Spring, Maryland, and flows in a southerly direction to its mouth in Bladensburg, draining an area of about 52 square miles; the Northeast Branch, formed by the junction of Paint Branch and Indian Creek, rises near Spencerville, Maryland, and flows in a southerly direction to its junction with the Northwest Branch, draining an area of about 75 square miles. The entire Anacostia River drainage area is rolling in character and the channels of the river and its branches are meandering, narrow, and silted. The Northwest Branch basin is long and narrow, with V-shaped valleys in the upper reach; in the lower reach, the stream overflows its banks and spreads out on a flood plain during freshets. Average depths in the branches at normal daily flows are approximately one foot. The Anacostia River basin is subject to three

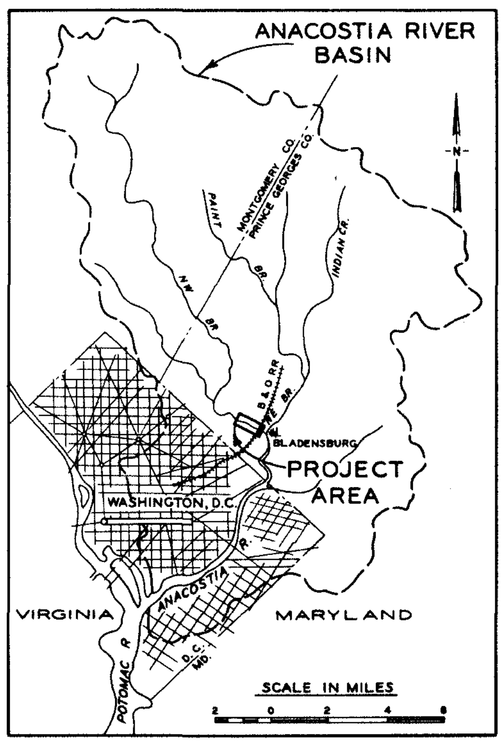


Fig. 1. Vicinity map

general classes of storms: the West Indian hurricanes, general cyclonic storms, and cloudbursts or local thunderstorms. Each of these can induce a flood in the Anacostia River, particularly the hurricane-type storm because the river basin is located about 100 miles inland from the Atlantic Coast. The lower reach of the Anacostia River is also affected by tides in the Potomac River.

## Description of Past Floods

2. The first storm for which records are available occurred 31 May-1 June 1889, and caused excessive rainfall over a wide area. This storm was centered in Pennsylvania with a maximum of 9.8 in. of rainfall, but also covered the Anacostia watershed. During 20-24 August 1933 a West Indian hurricane, accompanied by high winds and heavy rainfall, produced the highest flood of record in the Anacostia River Basin above the tidal section. The floods resulting from these two storms are the only major floods in the Anacostia Basin for which records are available. Data for the 1889 flood consist of a few scattered high-water marks, some of which are of doubtful reliability. A better record of the 1933 flood exists, as hydrographs are available for the Northwest Branch in addition to numerous flood marks in other sections of the basin.

## Design Flood

3. Determination of the floods to be used in the design of local protection works for the Northwest Branch was based on estimates of the maximum probable flood and the standard project flood. The maximum probable flood was derived from preliminary estimates of the maximum possible precipitation over the Anacostia watershed prepared by the Hydrometeorological Section of the United States Weather Bureau. The standard project flood was developed by the generalized method for small watersheds as outlined in Civil Engineer Bulletin No. 52-8. Peak flows for 38 transposable storms critically centered over the basin were computed for each branch of the Anacostia River and at the junction of the

branches using the unit hydrograph method. Of these 38 storms approximately 50 per cent would have produced peak flows greater than the actual maximum of record, that of August 1933. The standard project flood for the Northwest Branch, which is three times greater than the maximum flood of record, could be exceeded by three of the largest observed transposable storms. The design flood was selected on the basis of economic factors as well as considerations of the record and synthetic floods discussed above. Floods that have occurred or could occur on the Northwest Branch are as follows: maximum flood of record 8,000 cfs, maximum probable flood 58,000 cfs, maximum transposable flood 41,000 cfs, standard project flood 24,000 cfs, and the design flood 20,000 cfs.

## Flood Damages

4. The area flooded in 1933 by the Northwest Branch, about 120 acres, is located in the suburbs of Washington, D. C. The area that would be flooded by the design flood is about 28 per cent greater than that inundated in 1933. This incremental area, however, contains properties having a valuation approximately 42 per cent of that of the 1933 inundated area. The recurring and preventable losses from the 1933 flood along the Northwest Branch are estimated at about $92,000, based on 1942 costs; the average annual damage is estimated at about $33,000.

## Problem and Purpose of Model Study

5. The project provides for: channel improvement of Anacostia River from a point about 3 miles above the junction of the Anacostia and Potomac Rivers in the District of Columbia to the junction of the Northeast and Northwest Branches at Bladensburg, Maryland; channel improvement in the Northeast Branch from its mouth to a point about 1-1/2 miles upstream; channel improvement in the Northwest Branch from its mouth to a point about 1 mile upstream; and levees along both sides of the streams necessary to furnish protection to the areas adjacent to the improved channels and just below the intersection of the branches of the Anacostia River.

6. The project, as originally planned, included the use of a 550-ft-long section of high-velocity paved channel on the Northwest Branch a short distance upstream from the confluence of the Northwest and Northeast Branches in order to pass flood waters through two existing bridges; this would eliminate the need for reconstruction of the two bridges and reduce the cost of the project. Hydraulic computations indicated this to be feasible. However, because this reach of the Northwest Branch is affected by tidal flow and by backwater from the Northeast Branch, and because of the complicated nature of the design, it was considered desirable to check these computations by model tests. The specific purposes of the model study were to verify conclusions that (a) the paved channel as designed will induce the supercritical velocities necessary to lower water-surface elevations and provide adequate clearance under existing and proposed bridges, and (b) the hydraulic jump at the downstream end of the paved channel will be formed and retained on the paved section for the design flood through the expected range of discharges and tailwater elevations.

## PART II: THE MODEL

### Description

7. The model reproduced a 2100-ft reach of Northwest Branch just above its confluence with Northeast Branch (station 5+00 to station 26+00), and was of the fixed-bed type with the channel and floodway areas molded of sand-cement mortar to sheet-metal templets (see fig. 2). The bridge structures were fabricated of sheet metal with abutments molded in concrete. As constructed, the model included the originally proposed project for the reach as shown on plate 1 except for the installation of the Rhode Island Avenue highway bridge. At the time of construction provisions were made in the model for installation of the Rhode Island Avenue bridge with its upstream face at any point between stations 15+55 and 15+75 at an elevation to be determined from the model study.

8. The model was built to an undistorted scale of 1:30, model to prototype. This scale was selected because of the necessity for accurate simulation of flows for both low- and high-velocity channels. Other

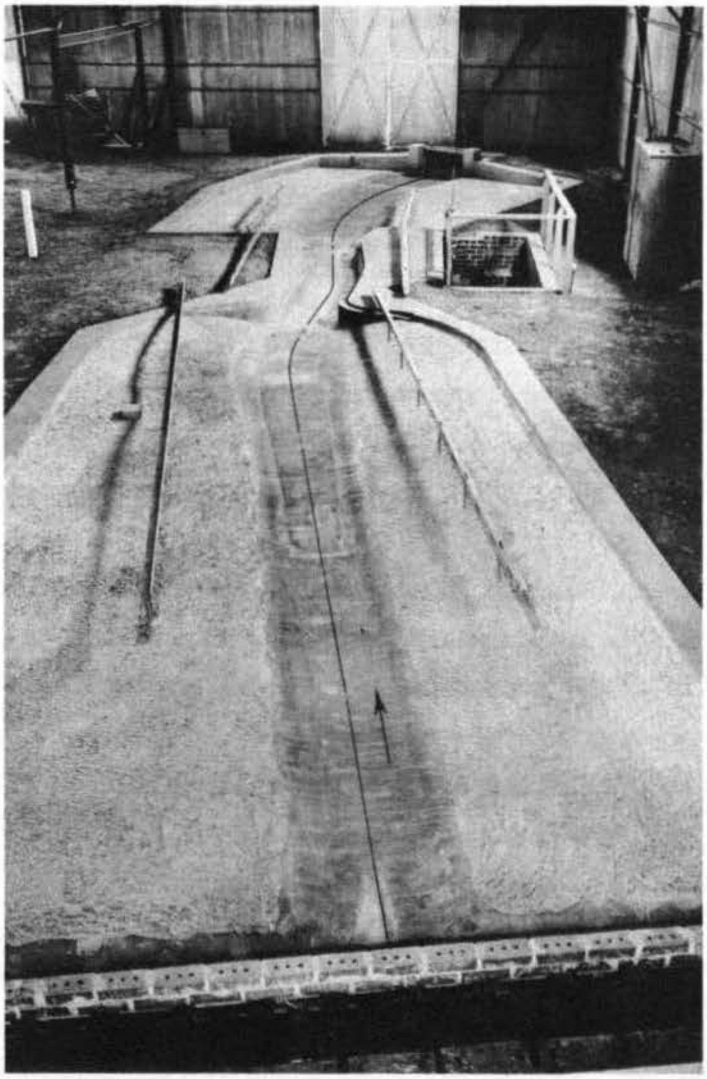

Fig. 2. Original design of model

scale ratios, which resulted from the linear scale ratio, were: area, 1:900; discharge, 1:4930; velocity and time, 1:5.48; and roughness (Manning's "n"), 1:1.763. Measurements of discharges, water-surface elevations, velocities, and current directions can be transferred quantitatively from model to prototype equivalents by means of these scale relationships.

## Model Appurtenances

9. Water was supplied to the model from a comprehensive circulating system and was measured by means of two venturi meters of different sizes to cover the range of discharge. Water-surface elevations at critical points along the channel were measured by means of piezometers located within the model channel and run to a centrally located gage pit; water-surface elevations at intermediate points were measured with a portable point gage supported on curb rails installed for that purpose. The tailwater elevation was controlled by an adjustable tailgate located at the downstream end of the model. Current velocities were measured by means of a pitot tube.

## Model Adjustment

10. Inclusion of the proposed Northwest Branch channel improvements in the initial model construction precluded adjustment of the model to known prototype data. This type of adjustment was not considered necessary since the proposed improvements would involve a radical change from existing conditions. The model was adjusted to reproduce roughness values assumed for the prototype and used in the theoretical computations upon which the design of channel improvements was based. The assumed prototype roughness values (Manning's "n") furnished by the Washington District were 0.030 for earth levee floodway sections, 0.025 for low-flow earth sections, 0.020 for riprapped surfaces, and 0.014 for paved sections of the channels; corresponding model roughness values were 0.0179, 0.0150, 0.0113, and 0.0079, respectively.

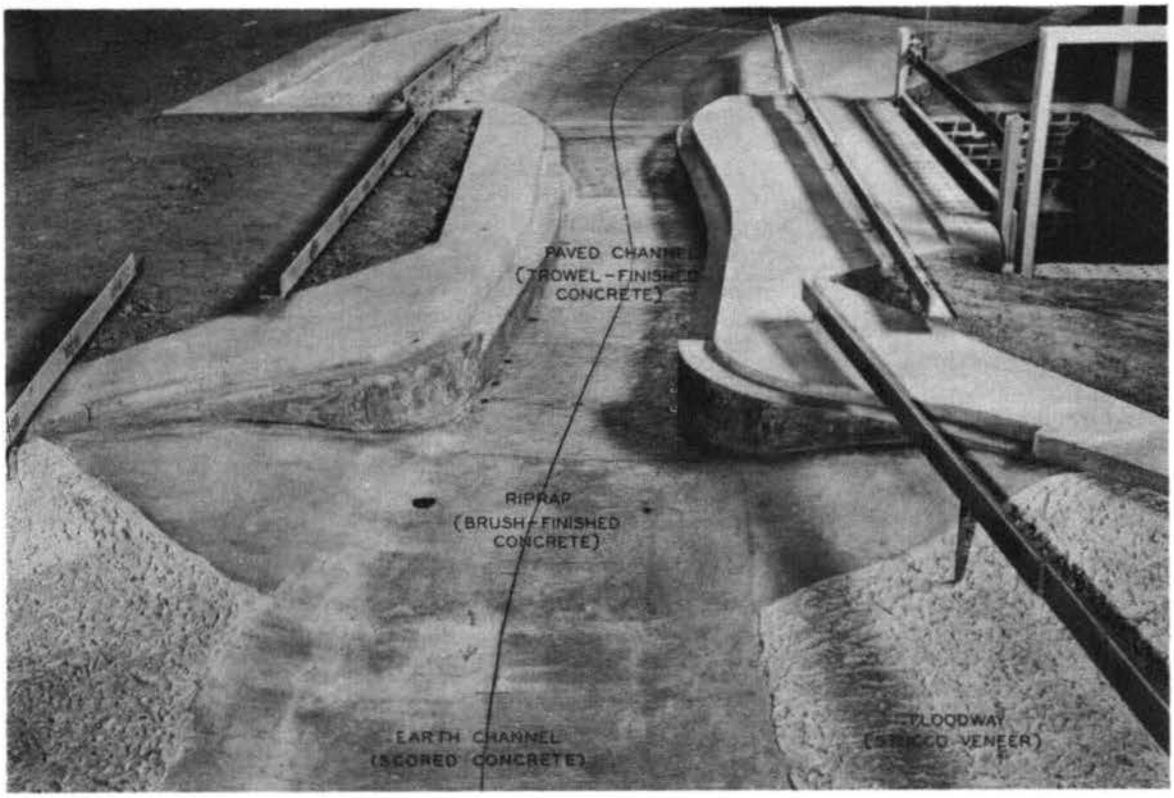


Fig. 3. Original channel design and types of roughness used in model

11. The derived values of roughness were incorporated into the model during design and construction and were based upon roughness standards developed from tests conducted by the Waterways Experiment Station.* The proper roughness was obtained by using light stucco, scored concrete, brushed concrete, and smooth, neat cement finish for the floodway section, low-flow earth sections, riprapped sections, and paved sections, respectively (see fig. 3). Supplementary slope was added to the model design slope within the paved reach since the theoretical roughness for the paved section could not feasibly be reproduced on the model.

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* Corps of Engineers, Waterways Experiment Station, <u>Roughness Standards for Hydraulic Models: Report No. 1, Study of Finite Boundary Roughness in Rectangular Flumes.</u> Technical Memorandum No. 2-364, Vicksburg, Miss. (June 1953).

# PART III: TESTS AND RESULTS

## Test Procedure

12. Model tests were concerned with the effectiveness of the proposed design in passing the design floods through the lower reach of Northwest Branch within the expected range of tailwaters, and with the development of modifications as required to overcome any undesirable conditions. All tests were conducted with constant flows. The desired flows were introduced at the upper end of the model and the tailwater elevations maintained at station 6+30 in accordance with a schedule submitted by the Washington District.

13. Data obtained during the model study consisted of inflow measurements, water-surface elevations at critical points, water-surface profiles along center line and walls of the high-velocity channel, velocity cross sections in areas of change in channel lining material, visual observations, and photographic records of flow conditions.

## Original Design

### Tests

14. As stated previously, tests of the original design (shown on plates 1-2 and figs. 2-3) were conducted to: (a) check the conclusions based upon computations that the paved channel as designed would induce the supercritical velocities necessary to provide clearance under the existing Capital Transit bridge and the proposed Rhode Island Avenue bridge, and that the hydraulic jump would be formed and retained on the paved section downstream of the Baltimore and Ohio Railroad bridge for the expected range of tailwater elevations; (b) determine what tailwater elevations would drown out the control or overtop the Capital Transit bridge seats; and (c) determine the tailwater elevations that would cause the hydraulic jump to move downstream of the paved area. Tests with this plan were conducted only with the 20,000- and 2,000-cfs flows.

### Results

15. The results of tests of the original design are shown in

table 1, plates 3-7, and photographs 1-8. Tests with the 20,000-cfs flow indicated the following:

a. Flow through the upstream reach of the model and the control section was generally good and evenly distributed (see photograph 1).

b. The hydraulic jump near the Baltimore and Ohio Railroad bridge occurred above the bridge with a tailwater elevation of 19.4 ft msl (photograph 2); moved just downstream of the bridge to station 12+50 with a tailwater elevation of 16.1 ft msl; remained on the paved section below the bridge at station 12+25 with a tailwater elevation of 15.4 ft msl; and moved downstream of the paved section when the elevation of the tailwater was lowered to 13.5 ft msl (photograph 3). When the hydraulic jump occurred above the Baltimore and Ohio Railroad bridge, a second jump occurred below the bridge.

c. Flow below the Baltimore and Ohio Railroad bridge was unstable and unevenly distributed across the channel, and resulted in excessive velocities in the earth channel downstream of the paved section. With a high tailwater, the flow was concentrated along the left side and moved toward the right side as the tailwater was lowered (see plates 4 and 6 and photographs 4-7).

16. The results of tests with the 2,000-cfs flow indicated the same general trends as obtained with the 20,000-cfs flow. The hydraulic jump occurred well above the Baltimore and Ohio Railroad bridge, and waves formed along the right side of the channel downstream (see photograph 8). Velocities observed in the unpaved section upstream varied from 5.9 to 7.1 fps, while velocities below the transition were as high as 9.6 fps with flow concentrated along the right side of the channel.

17. The results of tests of the original design indicated the necessity for some revisions in the high-velocity channel to provide a better distribution of flow and a more complete hydraulic jump below the Baltimore and Ohio Railroad bridge.

## Flow-stability Tests of Original Design

### Tests

18. Tests were conducted to determine the stability of flow within the paved channel of the original design. For this test, the upstream

face of the Rhode Island Avenue bridge was placed at station 15+59 with the bottom of the upstream girder at el 18.2 ft msl; the upstream girder of the Capital Transit bridge was placed at station 15+09 with the bottom of the upstream girder at el 17.3 ft msl. The following tests were conducted:

a. Test 1. With a stabilized flow of 20,000 cfs and a tailwater elevation of 19.4 ft msl, the tailwater was raised to drown out the Capital Transit and Rhode Island Avenue bridges. The tailwater was then returned to 19.4 ft msl to determine whether the original supercritical flow would be re-established.

b. Test 2. With a stabilized flow of 20,000 cfs and a tailwater elevation of 19.4 ft msl, the Rhode Island Avenue bridge was drowned out by simulated trash accumulation along its upstream face. The trash was then removed to determine whether or not flow would return to normal.

c. Test 3. With no flow in the channel and a tailwater elevation at 16.0 ft msl, flow was gradually increased to 20,000 cfs, using the following schedule as a guide:

| Northwest Branch Discharge cfs | Tailwater Elevation ft msl |
|---|---|
| 0 | 16.0 |
| 5,000 | 17.0 |
| 10,000 | 17.8 |
| 15,000 | 18.6 |
| 20,000 | 19.4 |

During this operation flow conditions were observed, with special attention given to drowning out of bridges and to the discharge at which supercritical flow obtained.

d. Test 4. This test was the same as test 3 except that the tailwater elevation started at 17.0 ft msl and flow was gradually increased to 15,000 cfs, using the following schedule as a guide:

| Northwest Branch Discharge cfs | Tailwater Elevation ft msl |
|---|---|
| 0 | 17.0 |
| 5,000 | 17.8 |
| 10,000 | 18.6 |
| 15,000 | 19.4 |

## Results

19. Water-surface elevations obtained during the flow-stability tests are shown in table 2. The results and observations made

during these tests indicated the following:

- a. Test 1. The water surface reached the bottom of the Capital Transit bridge when a tailwater elevation of 21.7 ft msl was reached; supercritical flow was eliminated and both the Capital Transit and Rhode Island Avenue bridges were drowned out when a tailwater elevation of 22.0 ft was reached; the Rhode Island Avenue bridge section did not act as an orifice under the conditions tested; the original supercritical flow readily re-established itself when the tailwater elevation was lowered from either 21.7 ft or 23.4 ft to 19.4 ft, regardless of the rate of lowering.
- b. Test 2. The accumulation of trash along the upstream face of the Rhode Island Avenue bridge caused the bridge to act as an orifice; removal of the trash did not restore normal flow (see table 2).
- c. Test 3. The water surface reached the bottom of the Capital Transit bridge when a flow of 10,000 cfs with a tailwater elevation of 17.8 ft msl was reached; the Capital Transit bridge was drowned out when a flow of 14,000 cfs with a tailwater of 18.4 ft was reached, and a small wave hit the bottom of the Rhode Island Avenue bridge near the center of the channel; supercritical flow was obtained when a discharge of 15,000 cfs with a tailwater elevation of 18.6 ft msl was reached (table 2).
- d. Test 4. The water surface reached the bottom of the Capital Transit bridge when a flow of 5,000 cfs with a tailwater elevation of 17.8 ft was reached; both the Capital Transit and the Rhode Island Avenue bridges were drowned out when a flow of 15,000 cfs with a tailwater elevation of 19.4 was reached (table 2). Supercritical flow was not obtained under the conditions tested.

## Plan A

### Description

20. Plan A was devised to overcome the undesirable conditions that obtained during the tests of the original design. The features of this plan were essentially the same as those of the original design with the exception of the following:

- a. Sills of varying heights were installed across the lower end of the stilling basin at station 11+70.
- b. The bed of the entire paved section of the channel was lowered 1 ft to increase the depth of the channel.

Tests

21. The above conditions were tested separately. These tests were preliminary in nature and a complete set of data was not obtained. The condition mentioned in subparagraph b on preceding page was simulated in the model by raising the elevations of the walls, bridge seats, and tailwater one foot.

Results

22. Data obtained during the test of plan A with a 4-ft sill are shown in table 3 and on plates 8 to 11. Although some improvement was obtained in flow conditions downstream below the Baltimore and Ohio Railroad bridge, the sill was not effective in providing the desired reduction in velocities in the unpaved channel downstream. Because of the uneven distribution of flow, sills 4 ft high or lower failed to produce a complete hydraulic jump; sills higher than 4 ft caused a second jump to occur below the sill.

23. The results of tests with the bed of the paved channel lowered one foot are shown in table 4 and on plates 12 to 15. The deepening of the channel did not in itself produce an even distribution of flow downstream of the Baltimore and Ohio Railroad bridge. Under the conditions simulated in this test the highest tailwater possible without drowning out the Capital Transit bridge was 21.7 ft msl, equivalent to a prototype elevation of 20.7 ft msl.

24. In evaluating the results of this test it should be considered that the model conditions were not an accurate simulation of conditions that would exist in the prototype with only the paved channel deepened, since in effect the unpaved channel and floodways upstream and downstream were also lowered in the model.

## Plan B

Description

25. The features of plan B are shown on plates 16 and 17 and included revisions in the original design as follows:

a. The bottom width of the low-flow channel upstream of the

paved channel was made uniform by eliminating the transition above the control section.

b. The width of the leveed floodway upstream of the paved channel was reduced.

c. The control section at the upstream end of the paved channel and the walled transition at the downstream end were modified.

d. The paved channel was deepened and the bed superelevated within the curved reach.

e. The width of the low-flow channel downstream of the paved channel was reduced from 100 ft to 50 ft.

Results

26. The principal results obtained during the tests of plan B are shown on plates 18 and 19. This plan produced considerable improvement in flow conditions for the design flow with a tailwater elevation of 15.4 ft msl (plate 19). However, with the higher tailwater elevation (19.4 ft msl) an undulatory jump occurred within the reach below the Capital Transit bridge, forming relatively large waves downstream to below the end of the paved channel (see plate 18). Also, with the high tailwater little or no clearance was obtained under the Capital Transit bridge.

## Plan C

Description

27. The features of plan C were developed from observation of the results of preliminary tests conducted to determine the effects of various modifications on flow conditions. Plan C is basically the same as plan B with modifications of the following items (see photographs 15 and 16 and plate 20):

a. Walls, slope, and transition within the control section of the upstream end of the paved channel.

b. Walls below the transition, within the high-velocity channel (raised 2 ft).

c. Elevation of the bridge seat for the proposed new Rhode Island Avenue bridge (raised from 18.2 ft msl to 20.0 ft msl).

d. Length and alignment of the walls and side-wall transitions below the Baltimore and Ohio Railroad bridge.

Results

28. The results of tests of plan C, shown in table 5 and on photographs 9 to 19 and plates 21 to 39, indicate the following:

a. Flow conditions upstream of the paved channel were generally good for all flows. Maximum bottom velocities measured at the upstream edge of the riprap section were about 9.0 fps and at the downstream edge about 11.5 fps (see plates 22, 30, and 35). Maximum velocities were measured during the 8,000-cfs flow with a tailwater elevation of 10.0 ft msl.

b. Minimum clearances of more than 6 ft under the Rhode Island Avenue bridge and more than 3 ft under the Capital Transit bridge were obtained with the 20,000-cfs flow and high tailwater. Supercritical flow was established through the reach with all flows and tailwater conditions tested.

c. Flow within the paved channel below the Capital Transit bridge was undulatory in nature, with the larger waves occurring along the center of the channel immediately below the Baltimore and Ohio Railroad bridge. Maximum waves 6 to 8 ft in height (peak-to-trough) were obtained with the 8,000-cfs flow and a tailwater elevation of 10.0 ft msl (see plate 34). A good hydraulic jump was obtained with all flows and tailwater conditions, with the exception of the 20,000-cfs flow with the high tailwater. In the latter case, the jump below the Baltimore and Ohio bridge was incomplete and waves along the center of the channel extended downstream (see photograph 12 and plate 21). When the Rhode Island Avenue bridge was drowned out by the simulated accumulation of trash, flow was re-established when trash was removed.

d. Flow below the paved channel was improved considerably for all flows. Maximum bottom velocities as high as 13.2 fps were measured within the earth channel during the 20,000-cfs flow with a tailwater elevation of 15.4 ft msl (see plate 28).

## PART IV: CONCLUSIONS

29. Model tests of the lower reach of the Northwest Branch indicated that the use of a high-velocity paved channel to pass flood flows up to 20,000 cfs under two existing bridges is feasible, but that considerable modification of the originally proposed design will be required to meet clearance requirements and improve flow conditions. Plan C, developed during the model study, will provide such necessary clearances and acceptable flow conditions; however, bottom velocities downstream of the paved channel will be rather high for discharges of design flood magnitude and will probably necessitate channel maintenance after such floods. In view of the low frequency of the design flood and the undeveloped status of the park lands at the downstream end of the paved channel, the Washington District considers an energy dissipating structure economically unjustified at this time.

Table 1

Water-surface Elevations, ft msl, with Original Design

| Gage* Number | Discharge, 20,000 cfs TW El 19.4 | TW El 16.1 | TW El 15.4 | TW El 13.5 | Discharge, 2,000 cfs TW El 4.0 |
|---|---|---|---|---|---|
| 1R | 23.94 | 23.94 | 23.94 | 23.94 | 8.19 |
| 1L | 23.97 | 23.94 | 23.94 | 23.94 | 8.25 |
| 2R | 23.91 | 23.91 | 23.94 | 23.94 | 8.04 |
| 2L | 23.91 | 23.88 | 23.94 | 23.94 | 8.01 |
| 3R | 23.07 | 23.07 | 23.07 | 23.07 | 6.54 |
| 3L | 23.31 | 23.28 | 23.19 | 23.31 | 6.69 |
| 4R | 16.95 | 16.95 | 16.92 | 16.95 | 5.31 |
| 4C | 18.54 | 18.51 | 18.48 | 18.48 | 5.70 |
| 4L | 17.40 | 17.37 | 17.37 | 17.37 | 5.55 |
| 5R | 16.41 | 16.38 | 16.38 | 16.38 | 5.13 |
| 5L | 16.53 | 16.50 | 16.50 | 16.50 | 4.98 |
| 6R | 15.48 | 15.48 | 15.48 | 15.48 | 4.74 |
| 6L | 15.39 | 15.39 | 15.42 | 15.36 | 4.53 |
| 7R | 13.53 | 13.53 | 13.53 | 13.50 | 3.96 |
| 7L | 13.35 | 13.35 | 13.38 | 13.35 | 3.81 |
| 8R | 12.99 | 12.87 | 12.87 | 12.87 | 2.79 |
| 8L | 8.26 | 8.01 | 8.01 | 7.98 | 1.32 |
| 9R | 16.68 | 11.82 | 11.85 | 11.76 | 4.23 |
| 9L | 16.68 | 11.97 | 12.00 | 11.97 | 2.70 |
| 10R | 16.89 | 10.68 | 11.83 | 10.80 | 3.30 |
| 10L | 16.77 | 12.84 | 12.78 | 12.78 | 3.78 |
| 11R | 16.20 | 11.07 | 10.71 | 10.68 | 3.12 |
| 11L | 15.45 | 12.30 | 11.16 | 11.07 | 3.78 |
| 12R | 19.50 | 15.78 | 13.50 | 5.97 | 4.08 |
| 12C | 19.05 | 16.20 | 15.00 | 8.34 | 3.90 |
| 12L | 19.05 | 16.47 | 14.88 | 13.17 | 3.96 |
| 13R | 19.47 | 17.52 | 16.05 | 11.43 | 3.96 |
| 13L | 19.62 | 16.56 | 15.18 | 13.23 | 3.93 |
| 14R | 19.53 | 16.62 | 15.15 | 13.41 | 3.93 |
| 14L | 19.56 | 16.47 | 15.24 | 13.77 | 3.93 |
| 15C | 19.41 | 16.08 | 15.39 | 13.50 | 3.99 |

* See plate 1 for gage locations.

Table 2

Water-surface Elevations, ft msl, Obtained in Flow-stability Tests with Original Design

| Gage Number | Discharge, cfs | | | | | |
|---|---|---|---|---|---|---|
| | Test 1 | | | Test 2 | Test 3 | Test 4 |
| | 20,000* | 20,000** | 20,000† | 20,000‡ | 15,000§ | 15,000** |
| 1R | 23.94 | 24.78 | 24.24 | 26.46 | 20.16 | 20.58 |
| 1L | 23.97 | 24.69 | 24.15 | 26.43 | 20.19 | 20.67 |
| 2R | 23.91 | 24.51 | 24.12 | 26.43 | 20.10 | 20.58 |
| 2L | 23.91 | 24.51 | 24.21 | 26.46 | 20.13 | 20.61 |
| 3R | 23.07 | 23.82 | 23.55 | 25.83 | 19.35 | 19.83 |
| 3L | 23.31 | 24.06 | 23.49 | 26.01 | 19.56 | 20.07 |
| 4R | 16.95 | 19.62 | 18.09 | 22.56 | 14.16 | 18.45 |
| 4C | 18.54 | 20.97 | 18.81 | 23.40 | 15.57 | 16.62 |
| 4L | 17.40 | 19.38 | 17.61 | 22.71 | 14.55 | 15.93 |
| 5R | 16.41 | 20.10 | 17.73 | 22.89 | 13.65 | 16.17 |
| 5L | 16.53 | 20.07 | 17.82 | 23.01 | 13.77 | 16.29 |
| 6R | 15.48 | 19.20 | 17.61 | 18.57 | 13.05 | 17.01 |
| 6L | 15.39 | 19.11 | 17.25 | 18.03 | 13.02 | 16.95 |
| 7R | 13.53 | 18.78 | 18.48 | 12.18 | 11.43 | 17.40 |
| 7L | 13.35 | 18.54 | 18.06 | 11.85 | 11.10 | 17.19 |
| 8R | 12.99 | 21.15 | 20.70 | 12.84 | 17.16 | 18.63 |
| 8L | 8.26 | 20.88 | 20.01 | 7.26 | 16.62 | 18.27 |
| 9R | 16.68 | 21.81 | 21.18 | 11.85 | 17.73 | 18.93 |
| 9L | 16.68 | 21.54 | 20.91 | 10.02 | 17.43 | 18.78 |
| 10R | 16.89 | 20.82 | 20.10 | 12.42 | 16.92 | 18.18 |
| 10L | 16.77 | 20.61 | 20.01 | 14.40 | 16.65 | 18.18 |
| 11R | 16.20 | 20.16 | 19.68 | 16.44 | 16.32 | 18.00 |
| 11L | 15.45 | 20.82 | 20.40 | 15.48 | 16.71 | 18.33 |
| 12R | 19.50 | 21.36 | 21.21 | 18.87 | 18.03 | 19.08 |
| 12C | 19.05 | 21.90 | 21.39 | 19.02 | 18.15 | 19.26 |
| 12L | 19.05 | 22.20 | 21.60 | 19.23 | 18.27 | 19.29 |
| 13R | 19.47 | 22.26 | 21.81 | 18.84 | 18.51 | 19.35 |
| 13L | 19.62 | 22.14 | 21.93 | 19.74 | 18.42 | 19.41 |
| 14R | 19.53 | 22.05 | 21.54 | 19.29 | 18.39 | 19.29 |
| 14L | 19.56 | 22.02 | 21.72 | 19.68 | 18.36 | 19.20 |
| 15C | 19.41 | 22.02 | 21.66 | 19.41 | 18.63 | 19.41 |
| Tailwater | 19.41 | 22.02 | 21.66 | 19.41 | 18.63 | 19.41 |

* Stable condition.

** Tailwater raised until Rhode Island Avenue and Capital Transit bridges drowned out.

† Tailwater raised until water surface reached bottom of Capital Transit bridge.

‡ Condition after simulated trash removed.

§ Tailwater lowered until supercritical flow obtained.

Table 3

Water-surface Elevations, ft msl, with Plan A, 4-ft Sill

| Gage Number | Discharge, 20,000 cfs TW El 19.4 | TW El 15.4 |
|---|---|---|
| 1R | 23.94 | 23.94 |
| 1L | 23.97 | 23.97 |
| 2R | 23.91 | 23.91 |
| 2L | 23.91 | 23.91 |
| 3R | 23.10 | 23.10 |
| 3L | 23.31 | 23.31 |
| 4R | 16.98 | 16.92 |
| 4C | 18.51 | 18.48 |
| 4L | 17.37 | 17.34 |
| 5R | 16.47 | 16.41 |
| 5L | 16.53 | 16.50 |
| 6R | 15.51 | 15.45 |
| 6L | 15.48 | 15.48 |
| 7R | 13.56 | 13.53 |
| 7L | 13.02 | 13.05 |
| 8R | 12.90 | 12.84 |
| 8L | 8.01 | 8.01 |
| 9R | 15.33 | 11.97 |
| 9L | 16.02 | 12.03 |
| 10R | 16.77 | 10.86 |
| 10L | 16.62 | 12.78 |
| 11R | 14.61 | 10.77 |
| 11L | 14.97 | 11.01 |
| 12R | 19.53 | 15.81 |
| 12C | 20.04 | 16.41 |
| 12L | 19.98 | 14.55 |
| 13R | 19.29 | 15.00 |
| 13L | 19.35 | 14.88 |
| 14R | 19.35 | 15.33 |
| 14L | 19.50 | 15.03 |
| 15C | 19.41 | 15.39 |

Table 4

Water-surface Elevations, ft msl, with Plan A Deepened Channel*

| Gage Number** | Discharge, 20,000 cfs TW El 20.4 | TW El 21.7 |
|---|---|---|
| 1R | 23.94 | 23.94 |
| 1L | 23.97 | 23.97 |
| 2R | 23.91 | 23.94 |
| 2L | 23.91 | 23.94 |
| 3R | 23.10 | 23.10 |
| 3L | 23.28 | 23.31 |
| 4R | 16.95 | 16.92 |
| 4C | 18.54 | 18.54 |
| 4L | 17.46 | 17.46 |
| 5R | 16.41 | 16.41 |
| 5L | 16.56 | 16.53 |
| 6R | 15.45 | 15.48 |
| 6L | 15.48 | 15.45 |
| 7R | 13.56 | 13.80 |
| 7L | 13.08 | 13.20 |
| 8R | 19.17 | 20.13 |
| 8L | 17.85 | 19.53 |
| 9R | 20.19 | 20.79 |
| 9L | 19.35 | 20.49 |
| 10R | 18.78 | 19.53 |
| 10L | 19.23 | 19.50 |
| 11R | 17.58 | 18.87 |
| 11L | 18.75 | 19.44 |
| 12R | 19.95 | 21.00 |
| 12C | 20.22 | 21.18 |
| 12L | 20.67 | 21.33 |
| 13R | 20.67 | 21.57 |
| 13L | 20.49 | 21.51 |
| 14R | 20.40 | 21.33 |
| 14L | 20.37 | 21.30 |
| 15C | 20.40 | 21.75 |

* For conversion to prototype subtract 1.0 ft. Elevations based on simulated model conditions.

** Gage locations shown on plate 1.

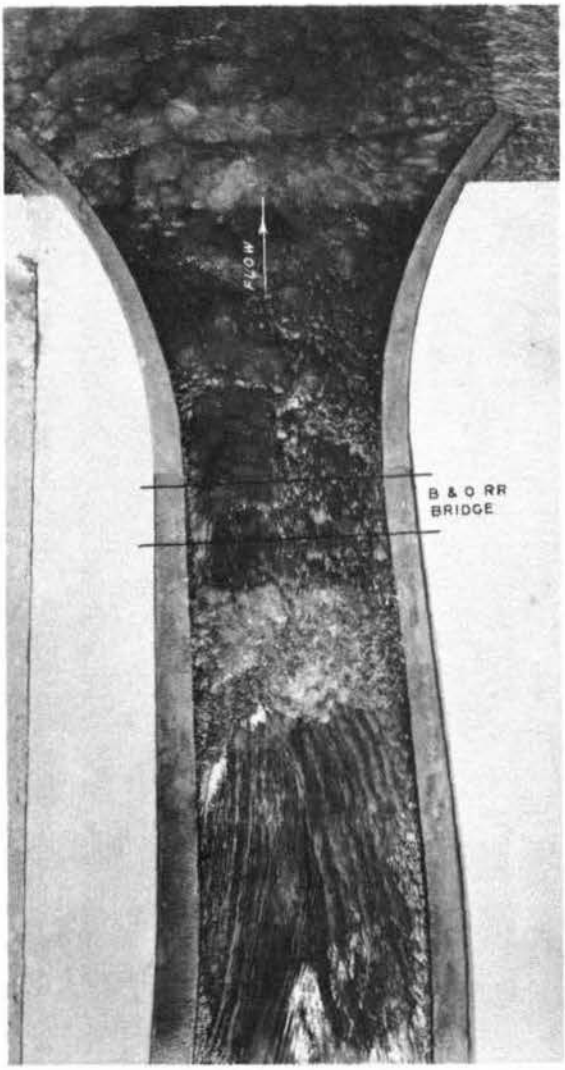
Table 5

Water-surface Elevations, ft msl, with Plan C

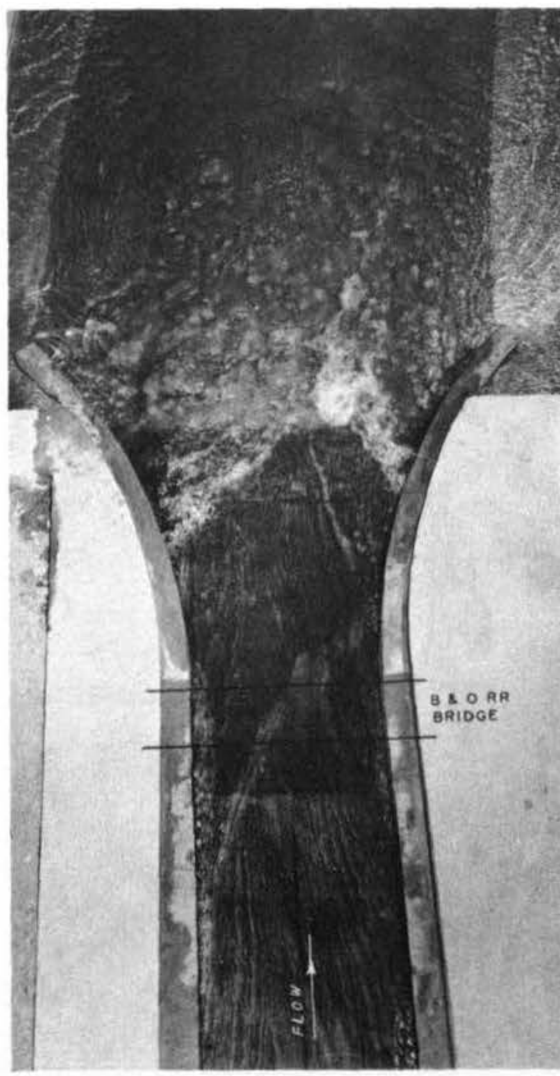
| Gage Number | Discharge, cfs 20,000 TW El 19.4 | 20,000 TW El 15.4 | 20,000* TW El 19.4 | 16,000 TW El 14.1 | 8,000 TW El 10.0 | 2,000 TW El 4.0 |
|---|---|---|---|---|---|---|
| 1R | 22.71 | 22.71 | 24.12 | 20.04 | 13.83 | 8.28 |
| 1L | 22.74 | 22.74 | 24.15 | 20.07 | 13.86 | 8.34 |
| 2R | 22.56 | 22.56 | 24.00 | 19.89 | 13.65 | 8.19 |
| 2L | 22.62 | 22.62 | 24.00 | 19.89 | 13.62 | 8.19 |
| 3R | 21.06 | 21.06 | 22.86 | 18.30 | 11.70 | 6.30 |
| 3L | 21.30 | 21.30 | 22.95 | 18.39 | 11.79 | 6.45 |
| 4R | 16.47 | 16.41 | 20.43 | 13.92 | 8.22 | 4.35 |
| 4C | 17.31 | 17.22 | 20.76 | 15.42 | 8.52 | 4.83 |
| 4L | 16.83 | 16.80 | 20.64 | 14.28 | 8.58 | 4.50 |
| 5R | 14.40 | 14.43 | 20.49 | 11.94 | 6.60 | 2.64 |
| 5L | 14.10 | 14.31 | 20.19 | 11.97 | 6.42 | 2.67 |
| 6R | 13.71 | 13.62 | 20.58 | 11.52 | 6.69 | 3.18 |
| 6L | 13.71 | 13.68 | 20.58 | 11.61 | 6.60 | 3.18 |
| 7R | 13.29 | 13.29 | 19.53 | 11.34 | 6.54 | 3.24 |
| 7L | 13.02 | 12.96 | 19.11 | 11.10 | 6.30 | 3.12 |
| 8R | 15.57 | 13.71 | | 11.70 | 5.61 | 2.70 |
| 8L | 14.10 | 13.05 | | 11.52 | 7.74 | 3.42 |
| 9R | 16.53 | 13.86 | | 12.03 | 7.95 | 3.09 |
| 9L | 16.35 | 12.39 | | 10.17 | 5.46 | 3.99 |
| 10R | 17.01 | 12.69 | | 10.86 | 7.20 | 4.23 |
| 10L | 16.77 | 12.84 | | 11.22 | 7.05 | 4.26 |
| 11R | 16.26 | 10.11 | | 8.37 | 7.92 | 4.23 |
| 11L | 16.86 | 10.59 | | 9.00 | 8.16 | 4.26 |
| 12R | 19.50 | 14.52 | | 13.20 | 8.55 | 4.62 |
| 12C | 19.47 | 14.46 | | 13.26 | 9.27 | 4.44 |
| 12L | 19.56 | 14.67 | | 13.14 | 9.36 | 4.41 |
| 13R | 19.44 | 15.21 | | 13.80 | 9.36 | 4.32 |
| 13L | 19.62 | 15.36 | | 13.44 | 9.45 | 4.44 |
| 14R | 19.35 | 15.33 | | 13.83 | 9.78 | 4.41 |
| 14L | 19.38 | 15.42 | | 14.07 | 9.84 | 4.44 |
| 15C | 19.41 | 15.39 | | 14.10 | 9.99 | 3.99 |

* Readings obtained with Rhode Island Avenue bridge flooded.

Photograph 1. Original design: surface currents in reach above control section. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl

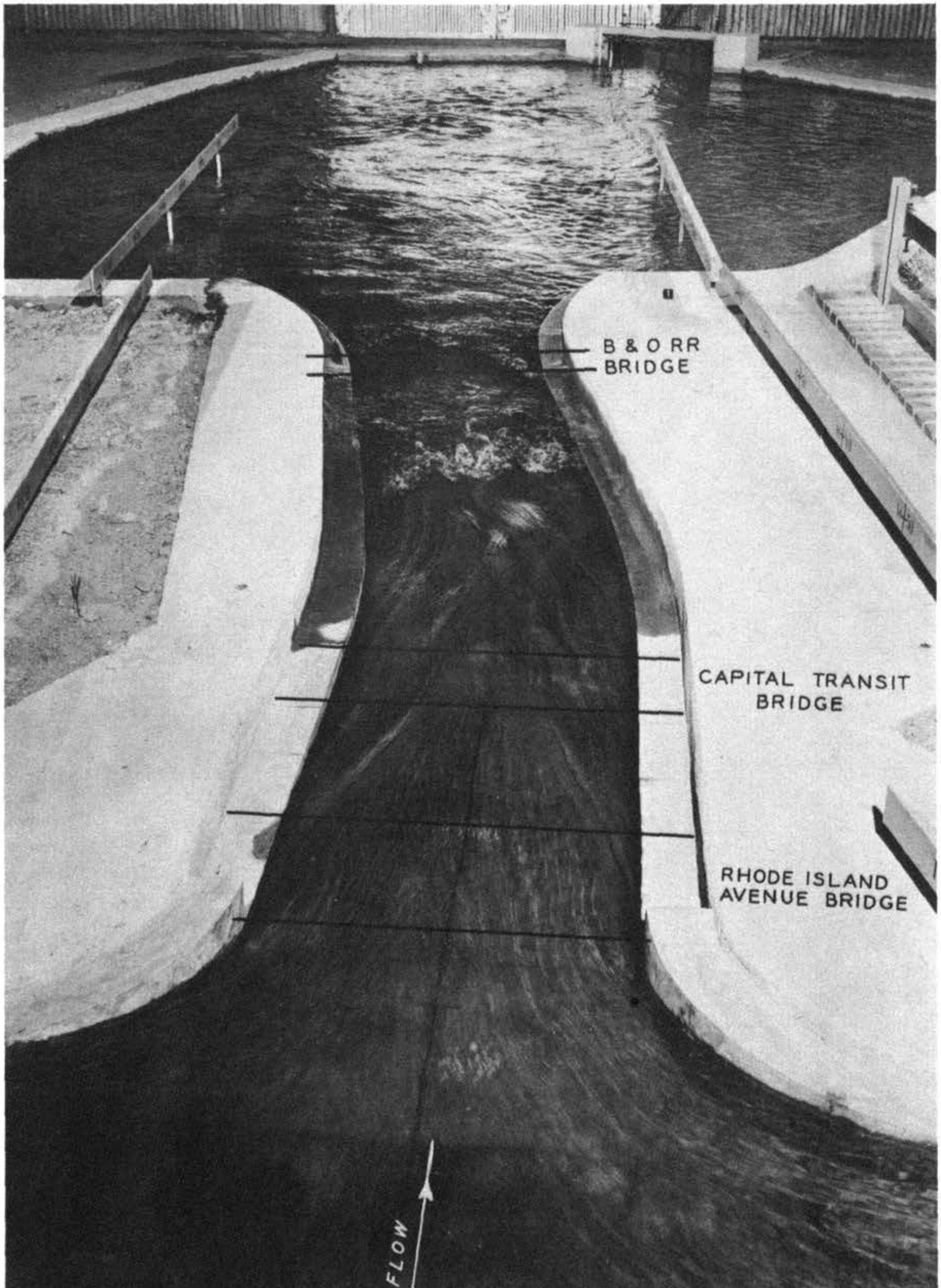



Photograph 2. Original design: positions of hydraulic jumps upstream and downstream of the Baltimore and Ohio Railroad bridge. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl

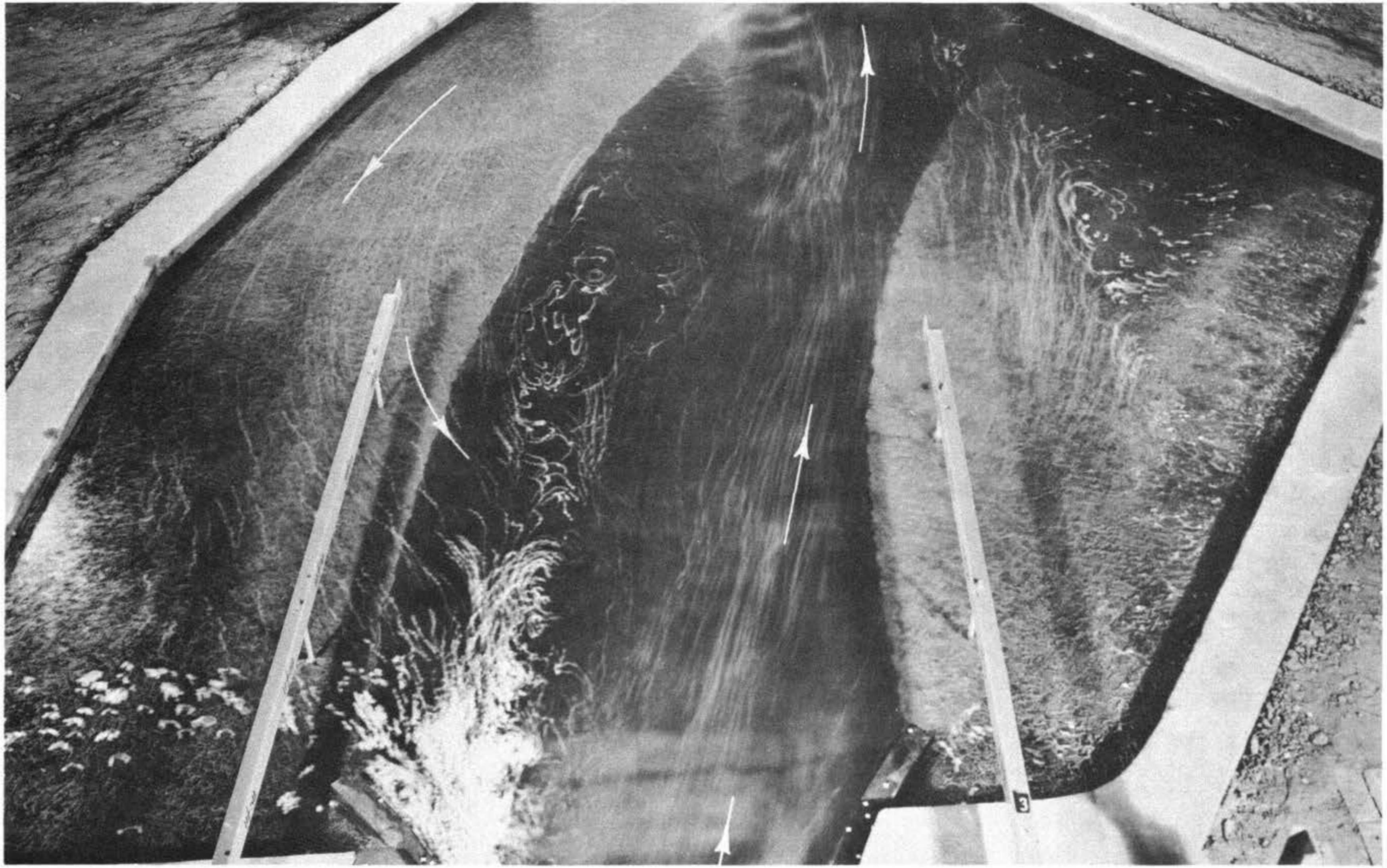



Photograph 3. Original design: position of hydraulic jump extending below the end of paved channel. Discharge, 20,000 cfs; tailwater elevation, 13.5 ft msl

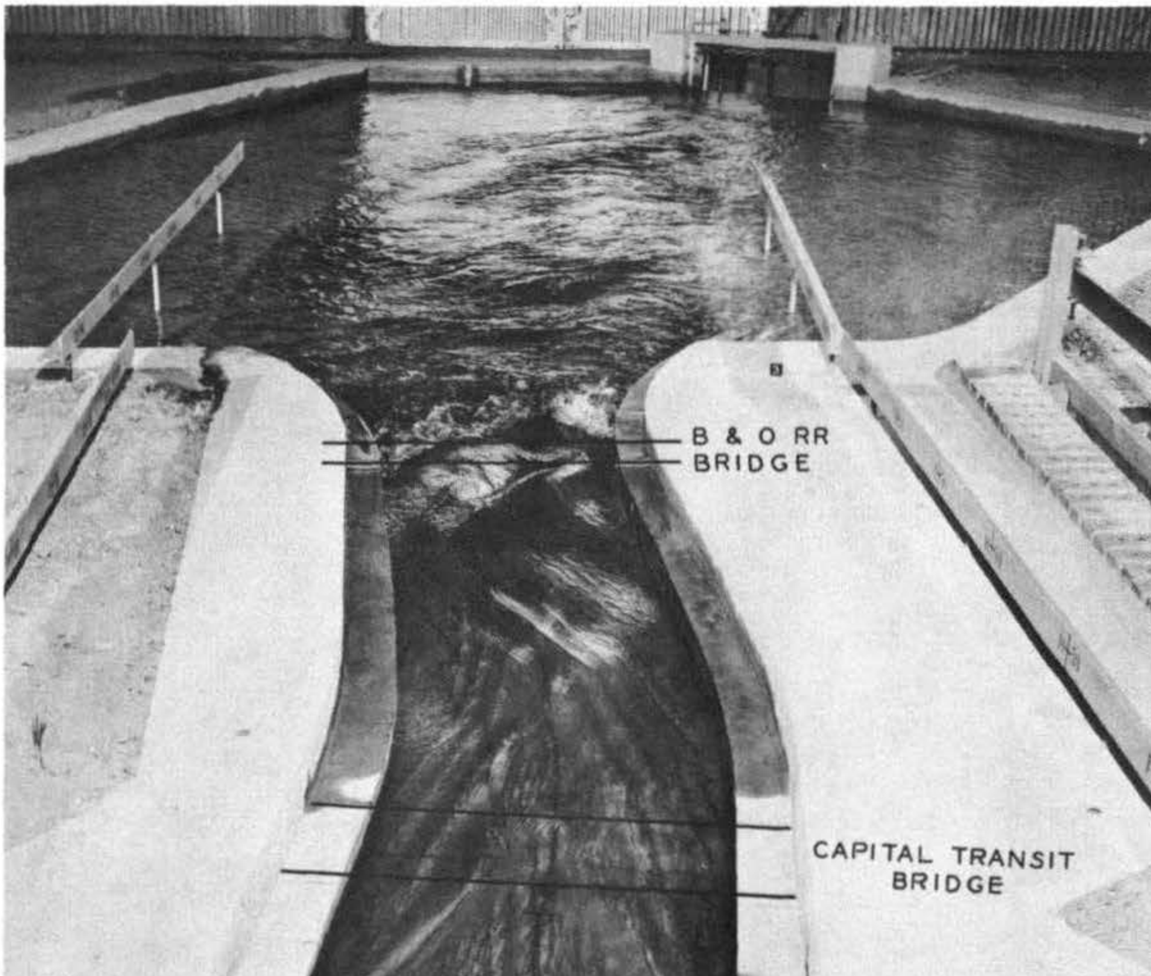
Photograph 4. Original design: surface currents below transition. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl



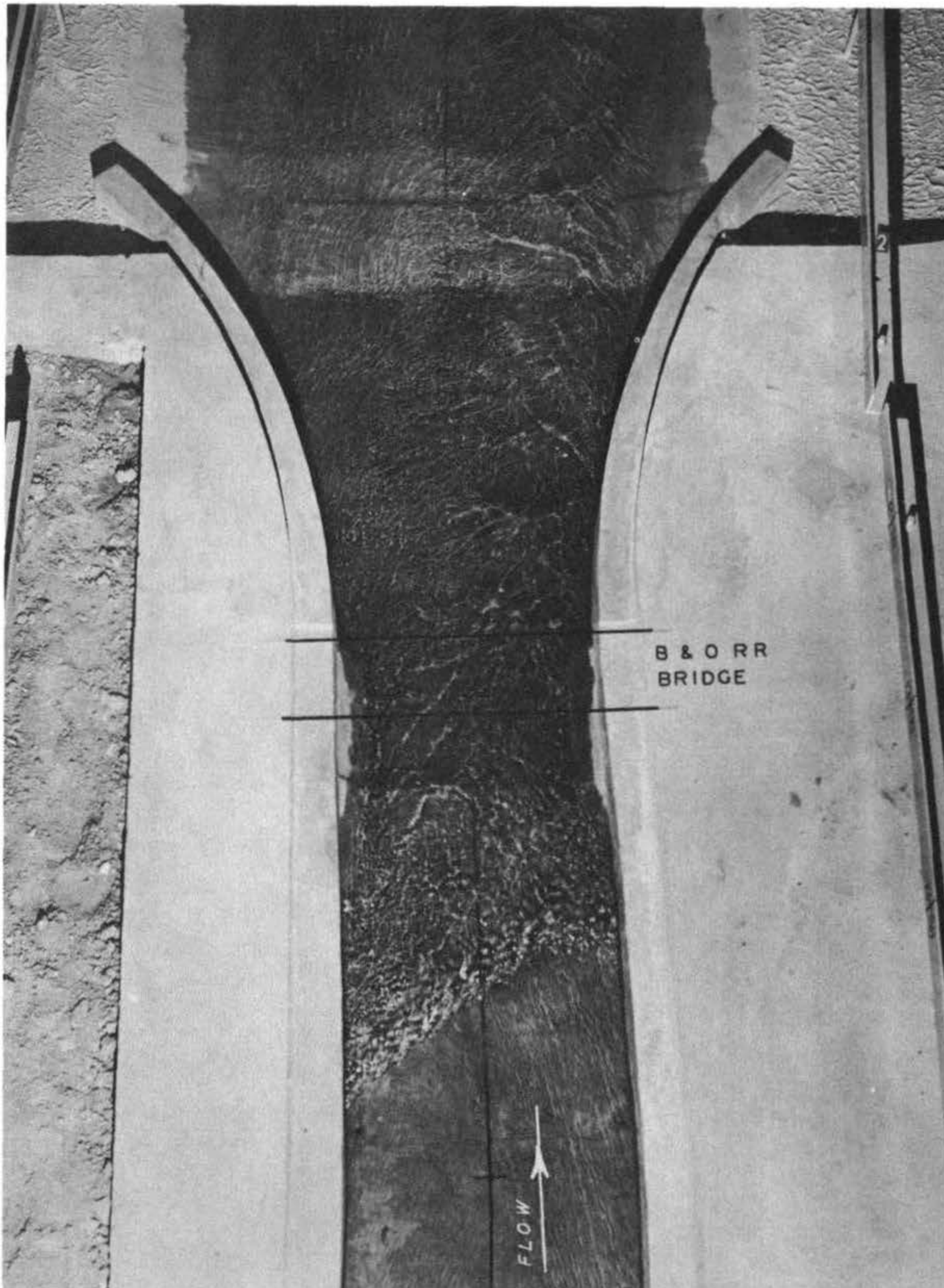

Photograph 5. Original design: flow conditions from upstream end of paved channel to lower end of model. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl



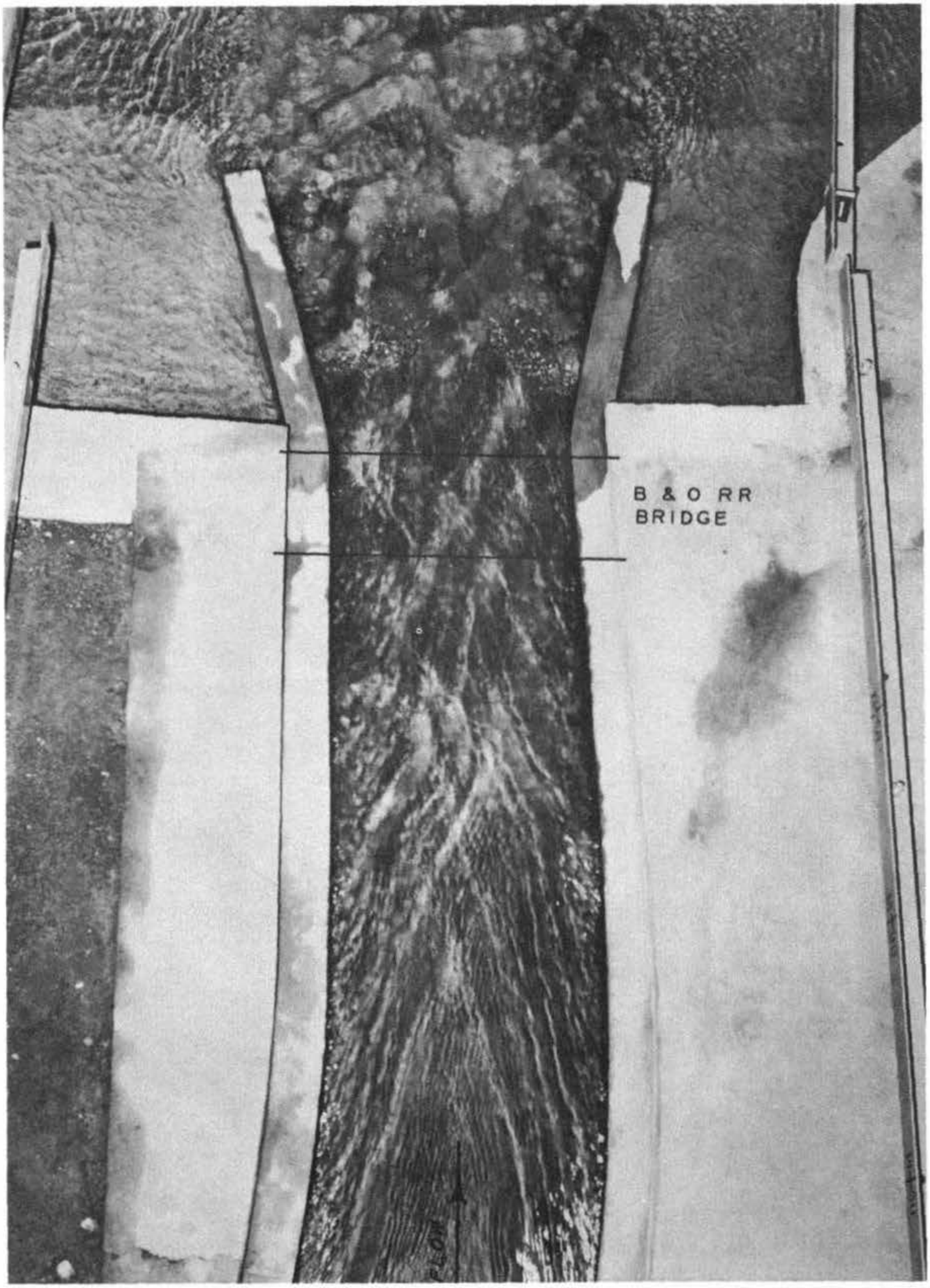

Photograph 6. Original design: surface currents below transition. Note concentration of flow towards right. Compare with photograph 4. Discharge, 20,000 cfs; tailwater elevation, 15.4 ft msl



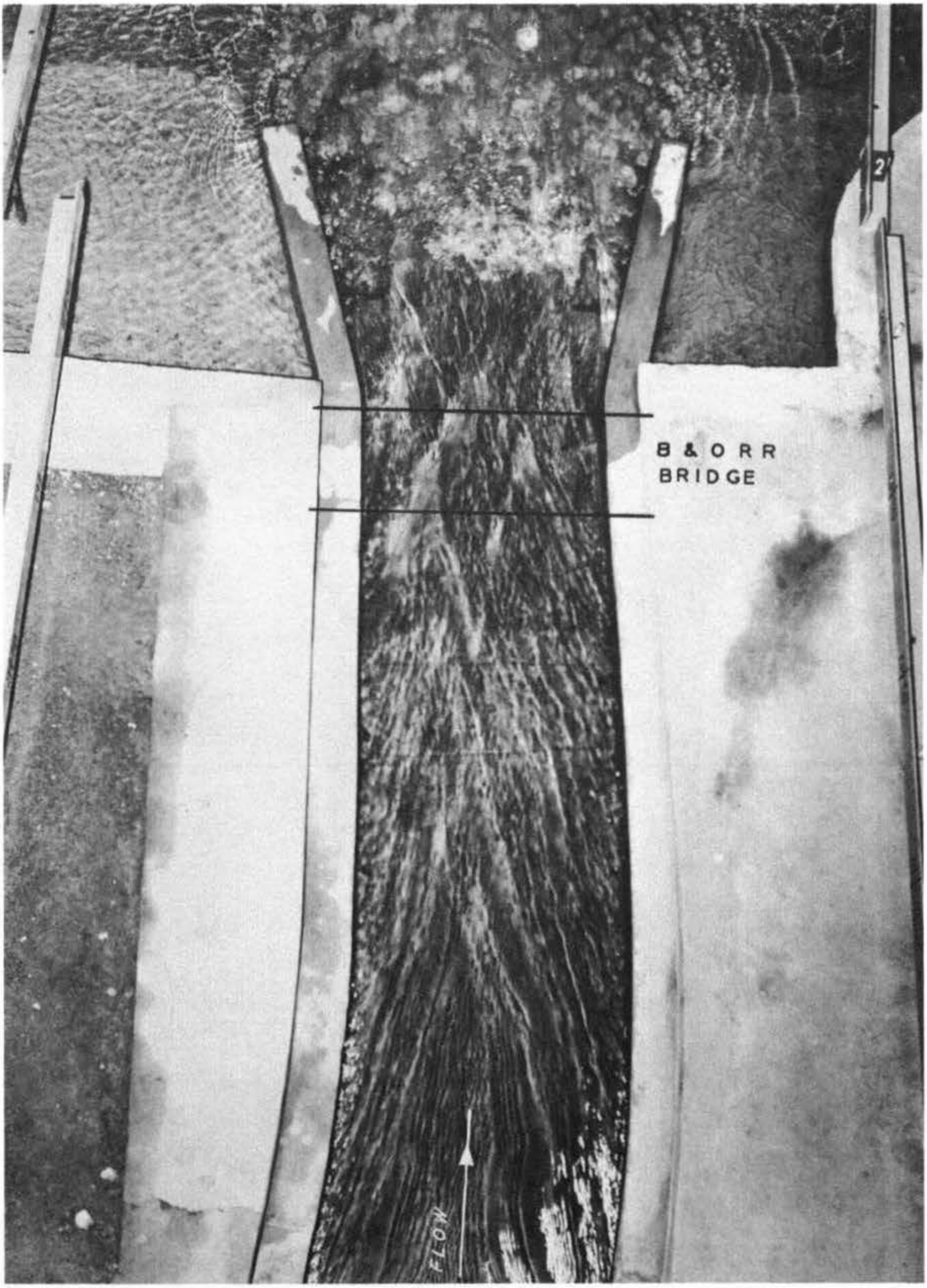

Photograph 7. Original design: flow conditions through the paved channel. Note hydraulic jump below Baltimore and Ohio Railroad bridge and waves just upstream. Discharge, 20,000 cfs; tailwater elevation, 15.4 ft msl



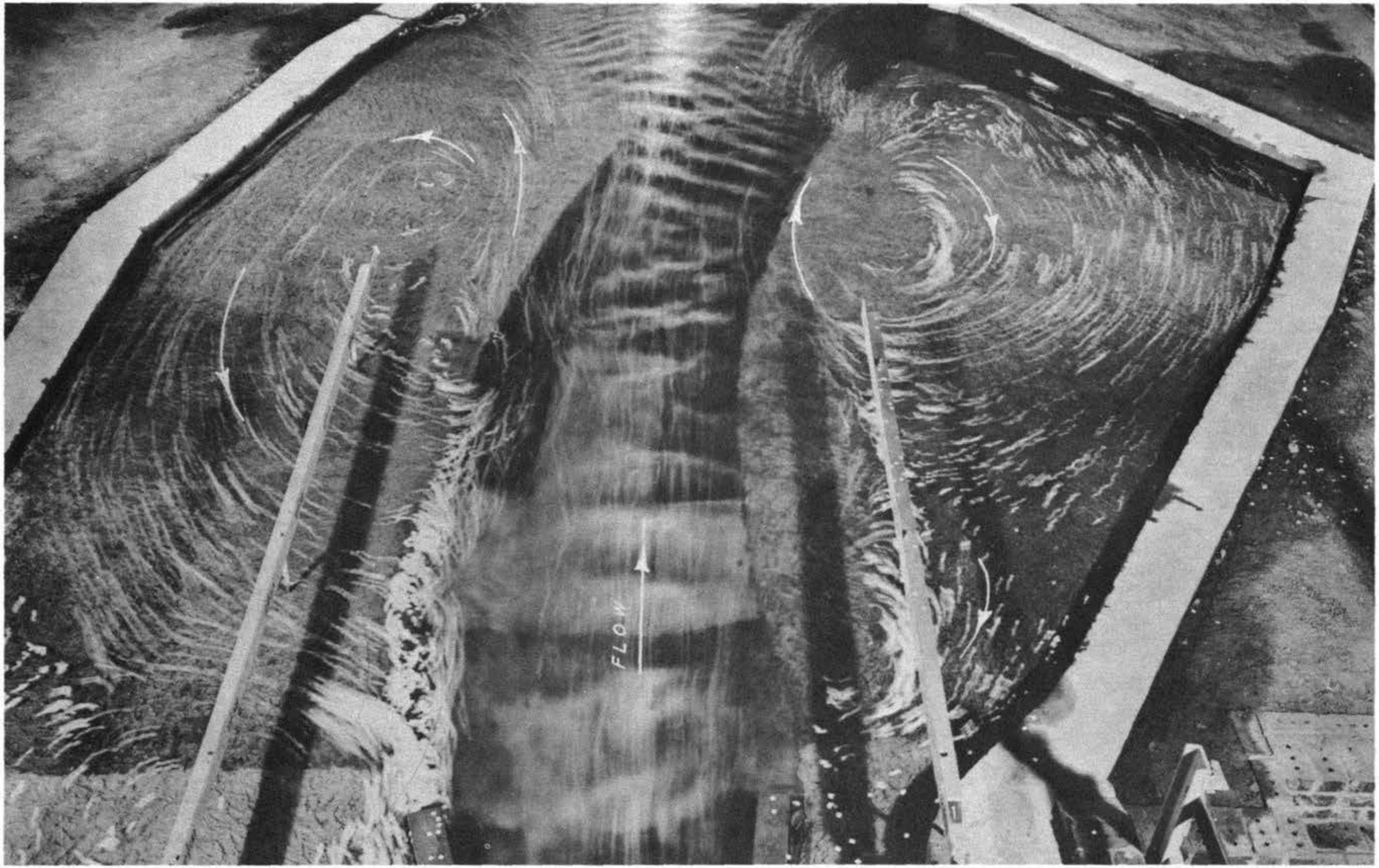

Photograph 8. Original design: flow conditions through paved channel with low discharge. Note hydraulic jump above the Baltimore and Ohio Railroad bridge and concentration of flow along right wall. Discharge, 2000 cfs; tailwater elevation, 4.0 ft msl



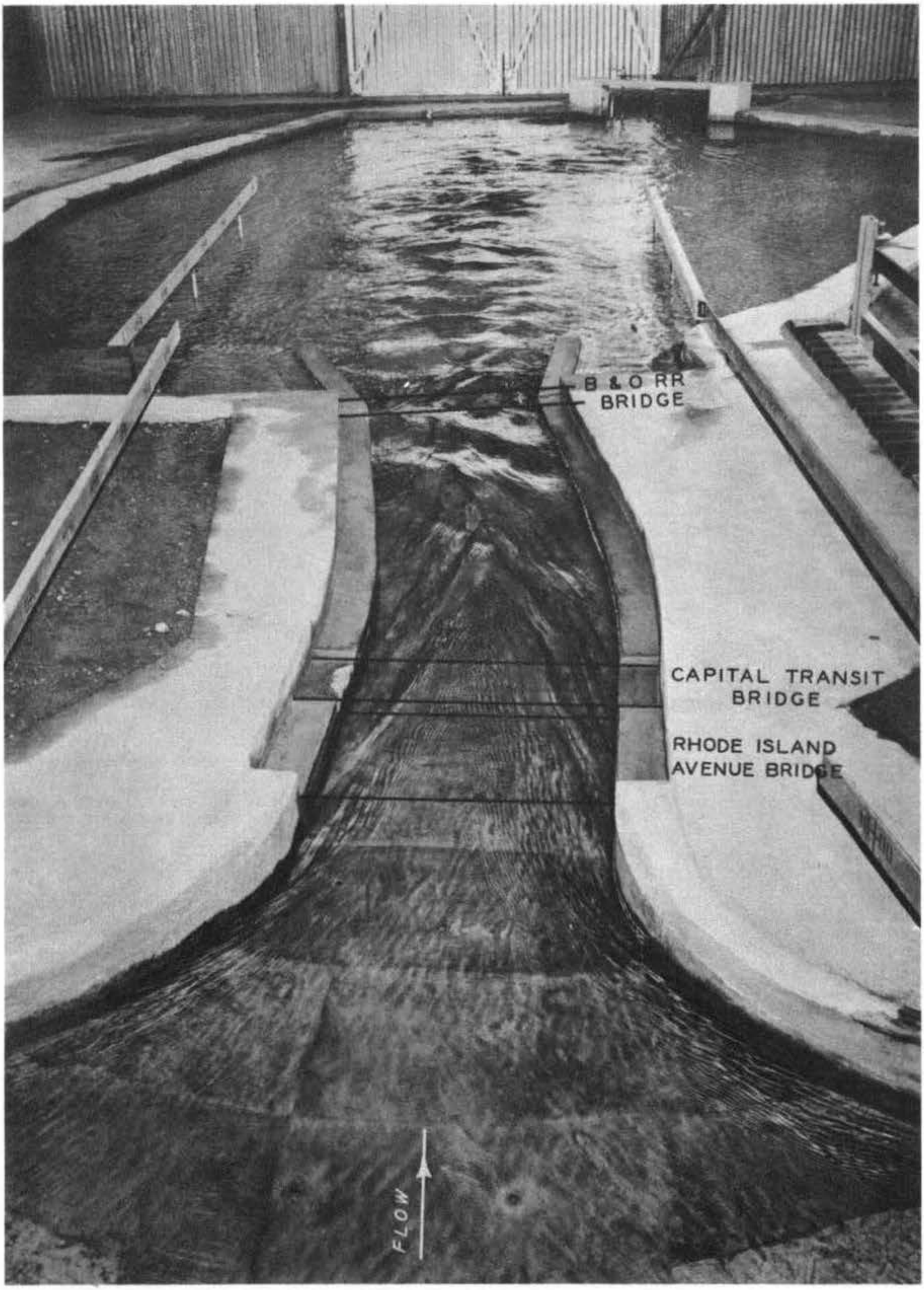

Photograph 9. Plan C: undulating hydraulic jump below the Baltimore and Ohio Railroad bridge. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl



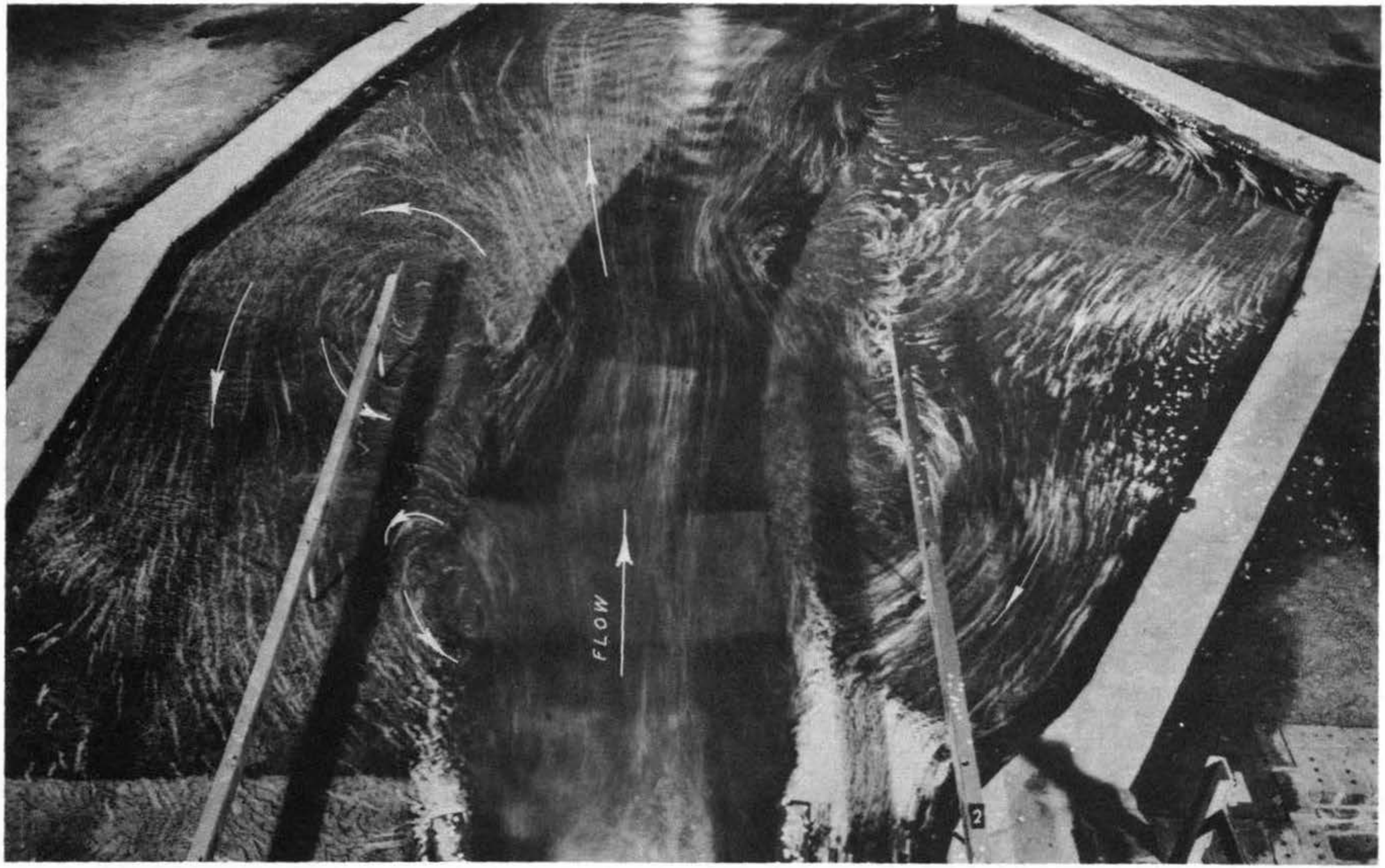

Photograph 10. Plan C: position of hydraulic jump below the Baltimore and Ohio Railroad bridge. Discharge, 20,000 cfs; tailwater elevation, 15.4 ft msl



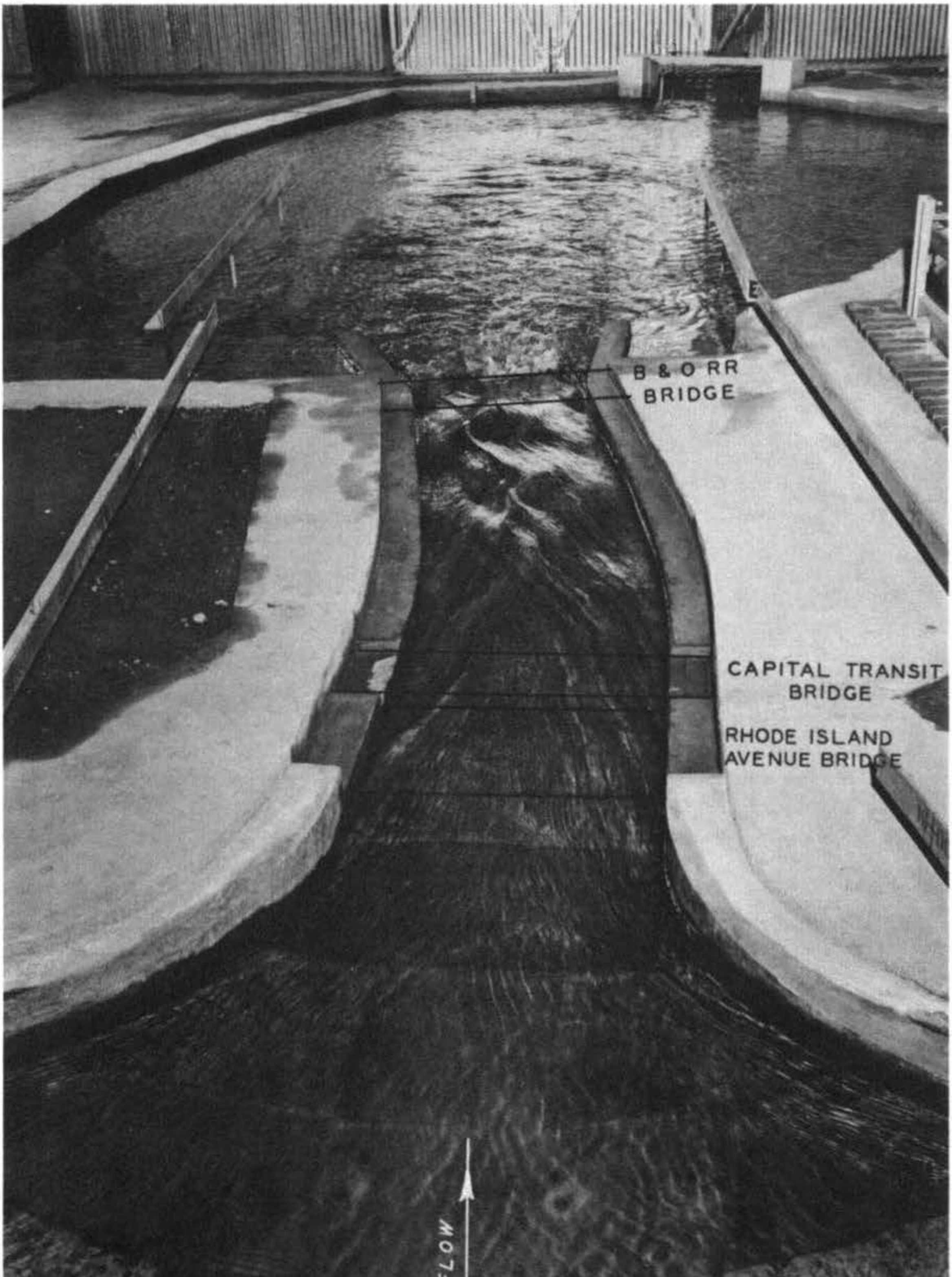

Photograph 11. Plan C: surface currents below transition. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl



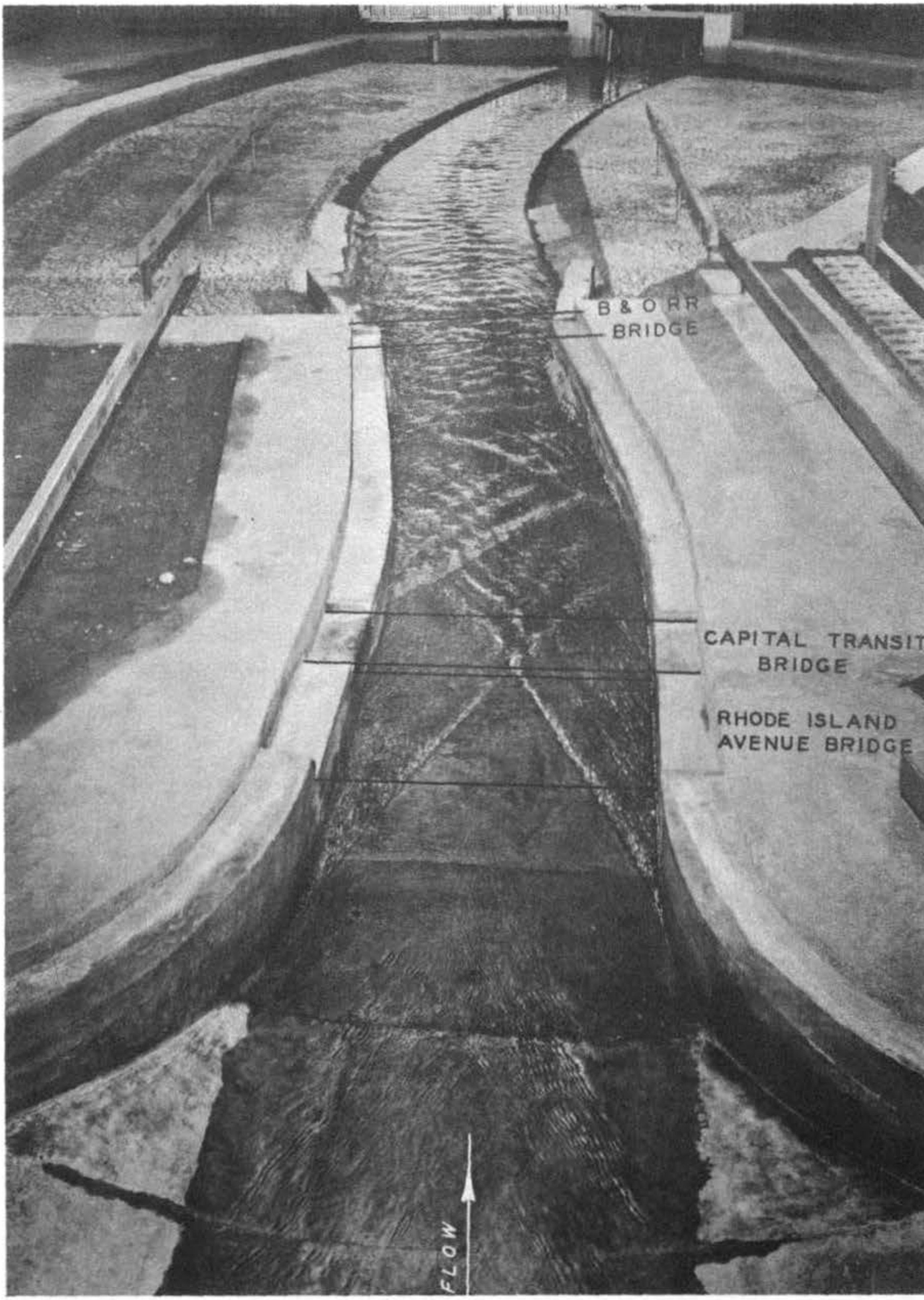

Photograph 12. Plan C: flow conditions from upstream end of paved channel to lower end of model. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl



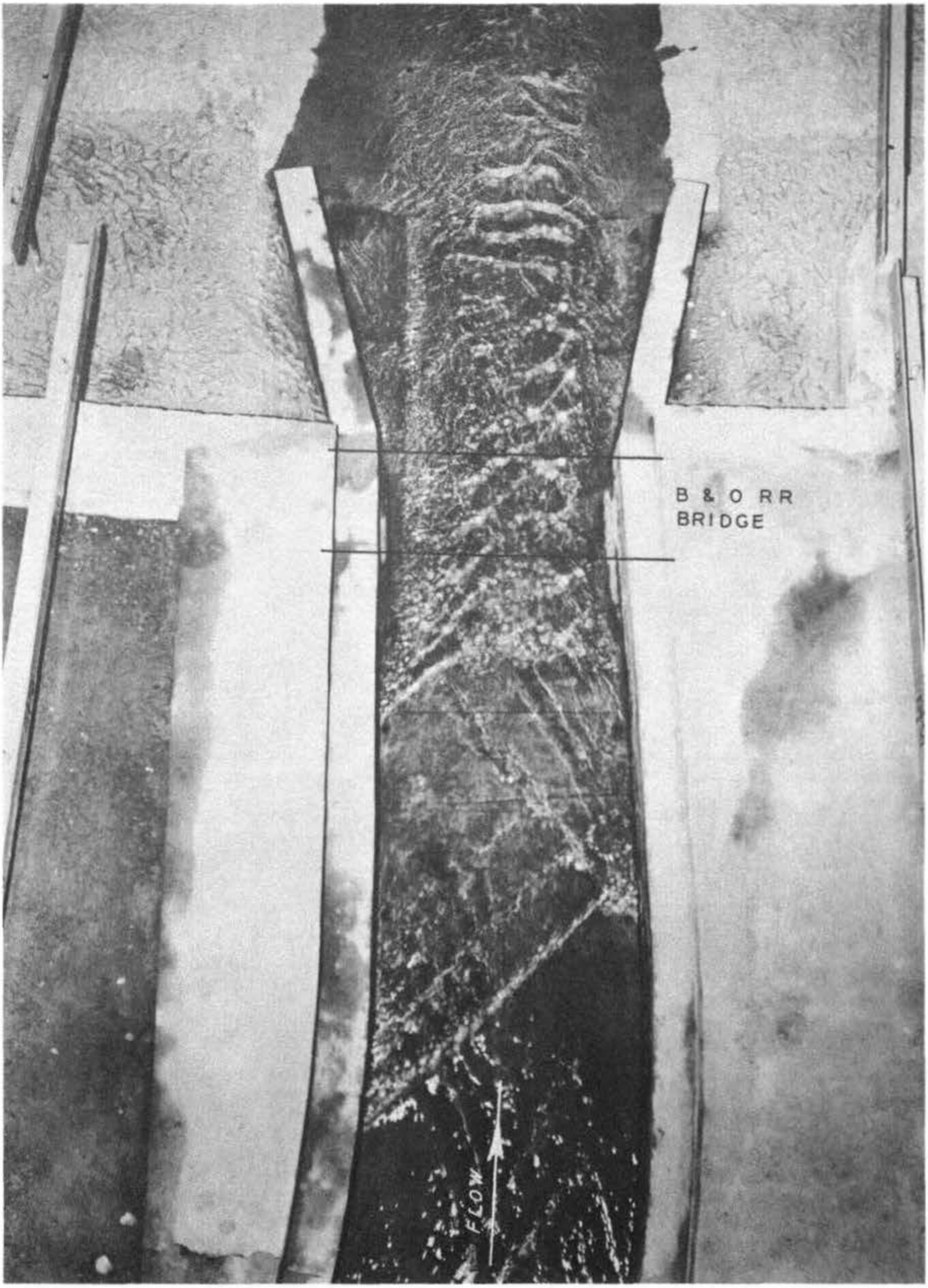

Photograph 13. Plan C: surface currents below transition section. Discharge, 20,000 cfs; tailwater elevation, 15.4 ft msl



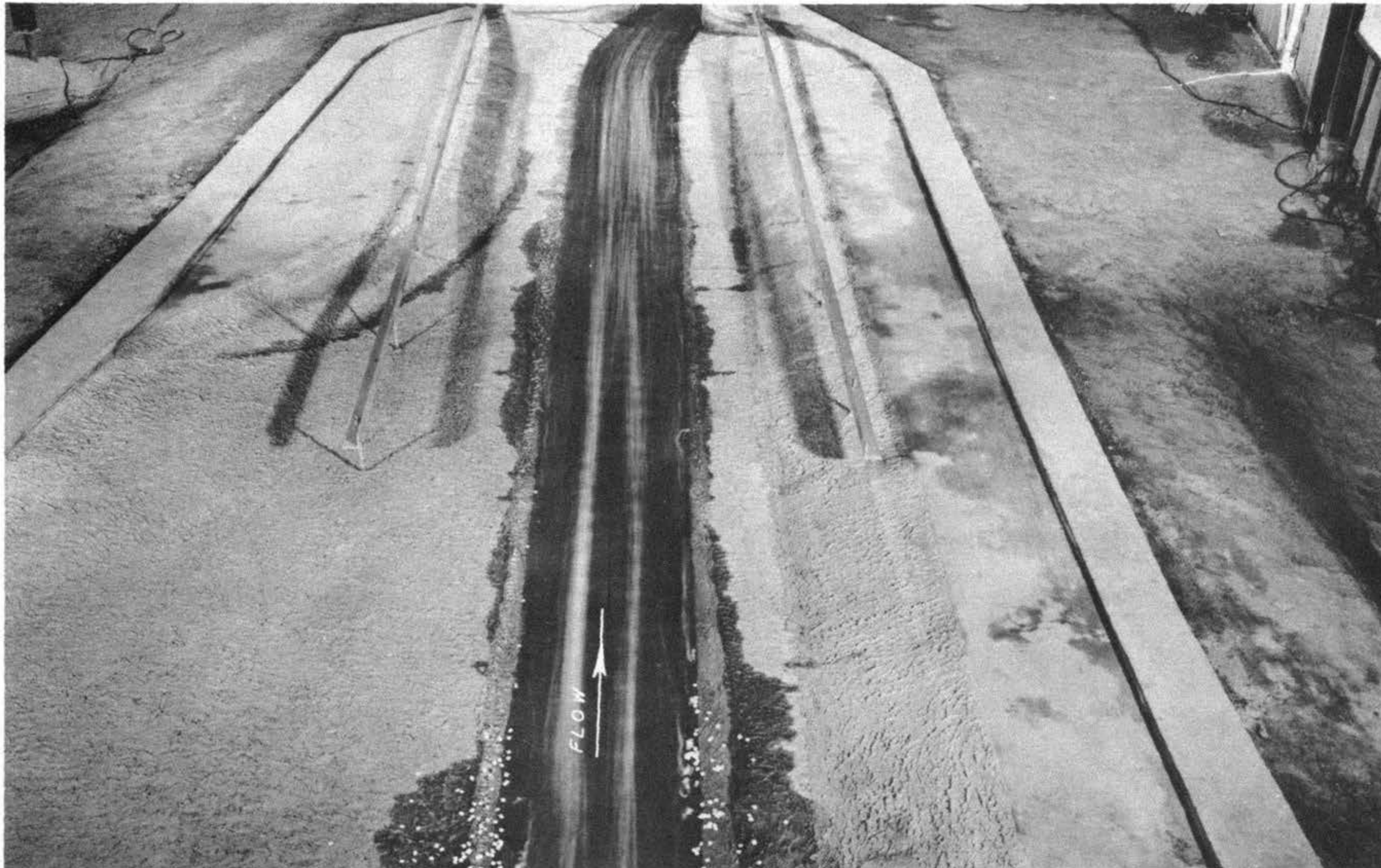

Photograph 14. Plan C: flow conditions through paved channel. Discharge, 20,000 cfs; tailwater elevation, 15.4 ft msl. Compare with photograph 7



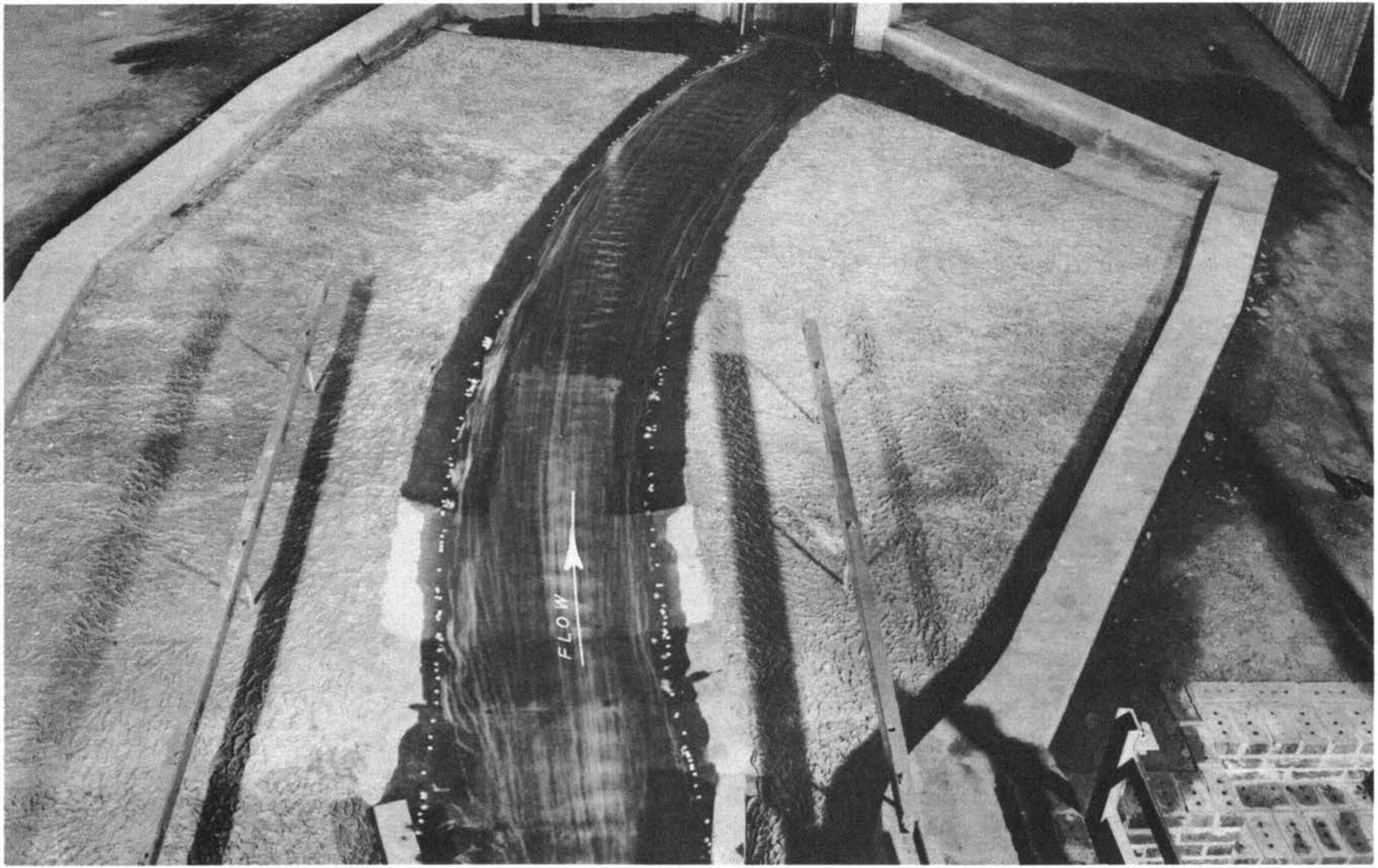

Photograph 15. Plan C: flow conditions from upstream end of paved channel to lower end of model. Discharge, 2000 cfs; tailwater elevation, 4.0 ft msl



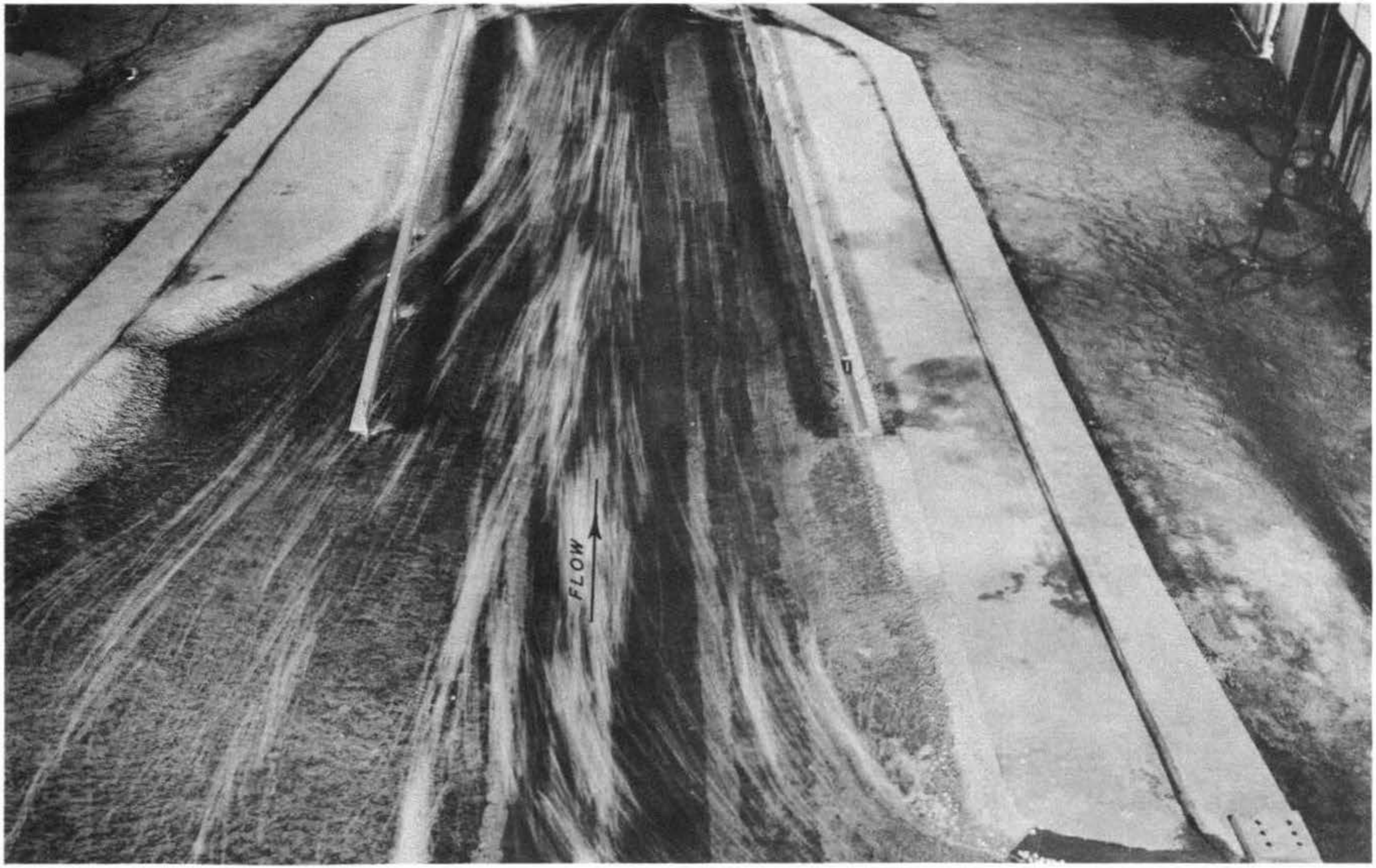

Photograph 16. Plan C: hydraulic jump just above Baltimore and Ohio Railroad bridge. Discharge, 2000 cfs; tailwater elevation, 4.0 ft msl. Compare with photograph 8



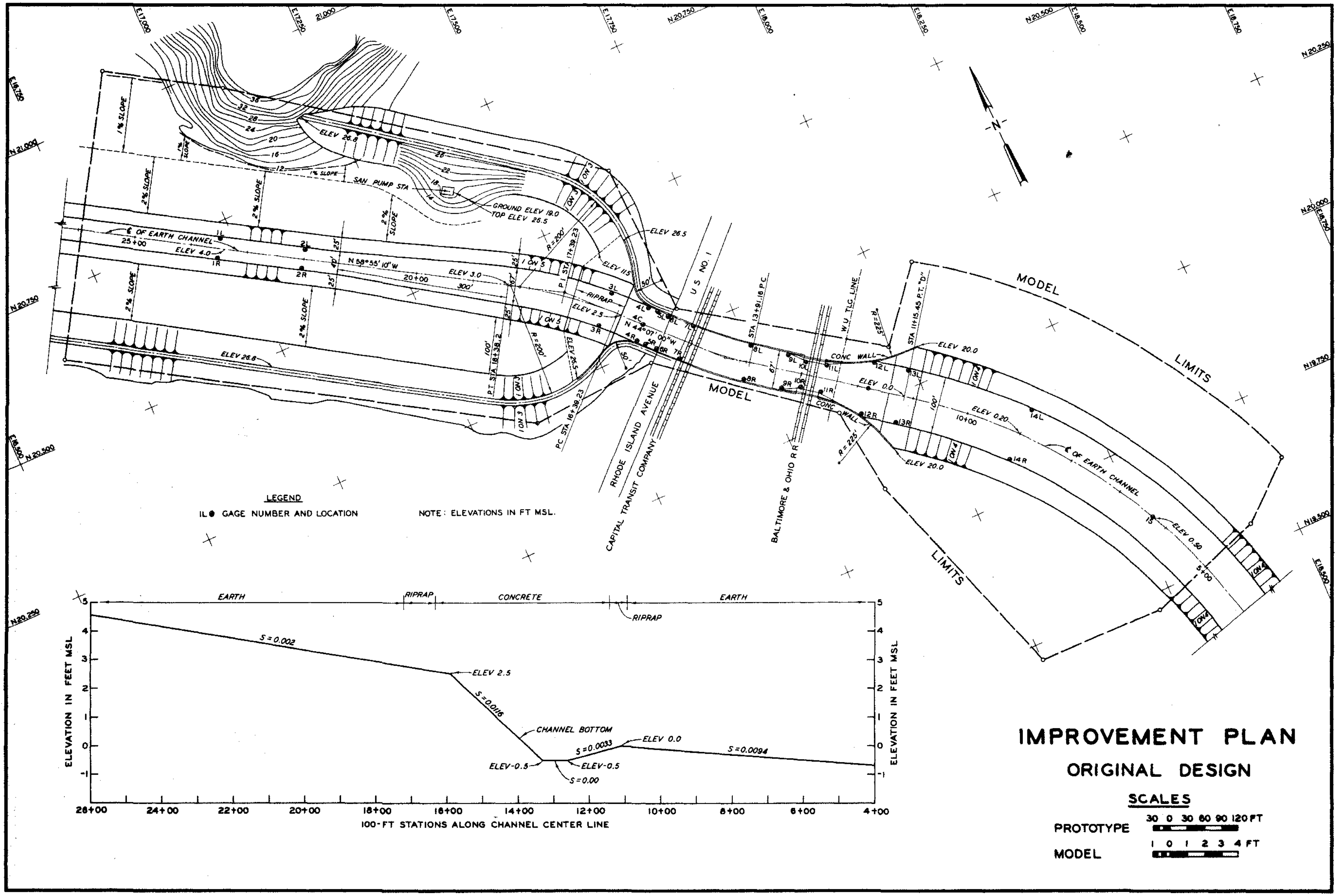

Photograph 17. Plan C: surface current directions in section of model upstream of paved channel. Discharge, 2000 cfs; tailwater elevation, 4.0 ft msl




Photograph 18. Plan C: surface current directions in section of model downstream of paved channel. Discharge, 2000 cfs; tailwater elevation, 4.0 ft msl



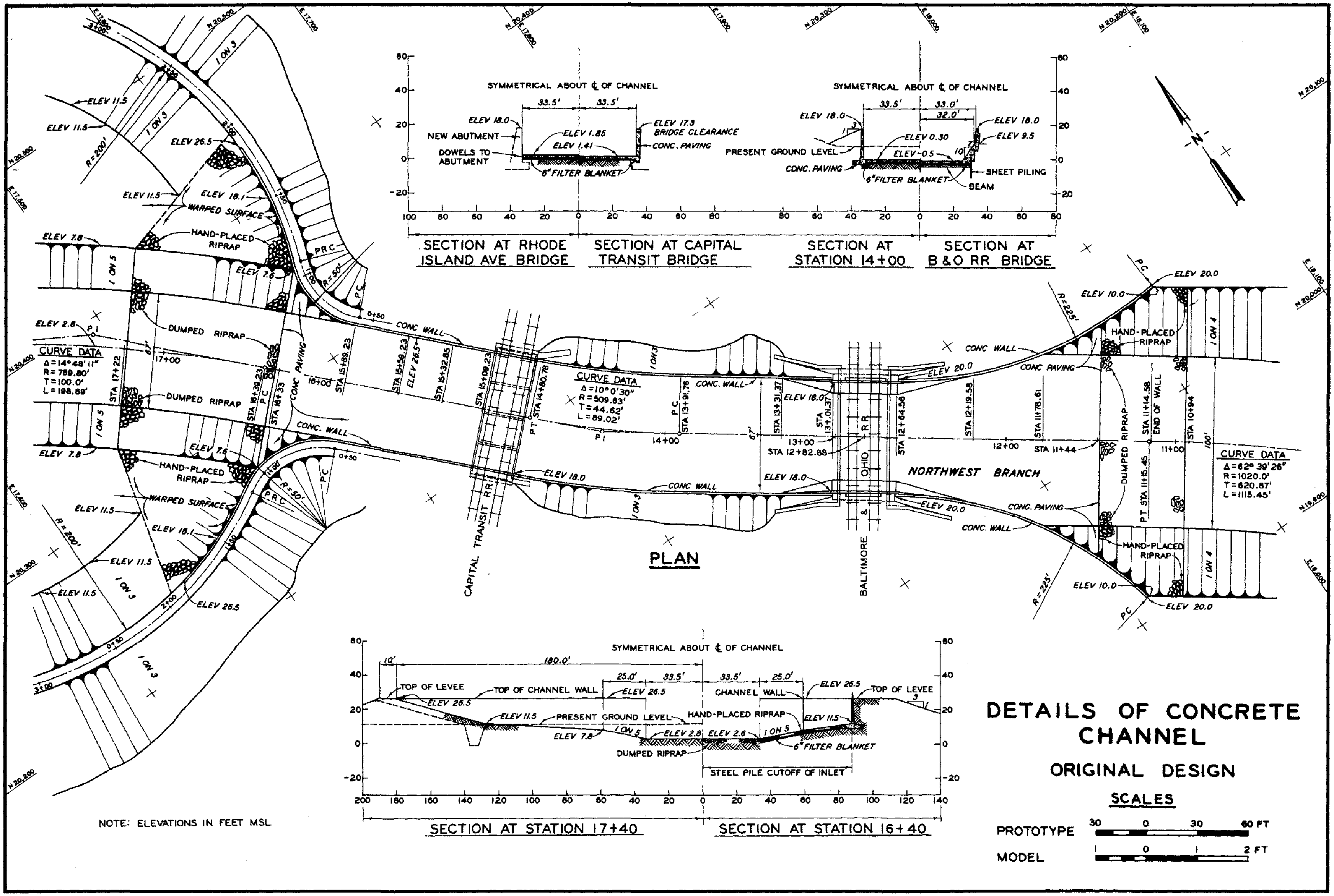

Photograph 19. Plan C: surface currents in the reach above the control section. Discharge, 20,000 cfs; tailwater elevation, 19.4 ft msl



MODEL LIMITS
MODEL LIMITS
SAN PUMP STA
GROUND ELEV 19.0
TOP ELEV 26.5
ELEV 26.8
ELEV 26.5
ELEV 20.0
℄ OF EARTH CHANNEL
N 58°55' 10" W
N 44°07' 00" W
US NO. 1
RHODE ISLAND AVENUE
CAPITAL TRANSIT COMPANY
BALTIMORE & OHIO R R
W U TLG LINE
CONC WALL
RIPRAP
LEGEND
1L● GAGE NUMBER AND LOCATION
NOTE: ELEVATIONS IN FT MSL.
EARTH
RIPRAP
CONCRETE
EARTH
RIPRAP
S = 0.002
ELEV 2.5
S = 0.0116
CHANNEL BOTTOM
ELEV-0.5
S = 0.00
ELEV-0.5
S = 0.0033
ELEV 0.0
S = 0.0094
ELEVATION IN FEET MSL
100-FT STATIONS ALONG CHANNEL CENTER LINE
IMPROVEMENT PLAN
ORIGINAL DESIGN
SCALES
PROTOTYPE 30 0 30 60 90 120 FT
MODEL 1 0 1 2 3 4 FT

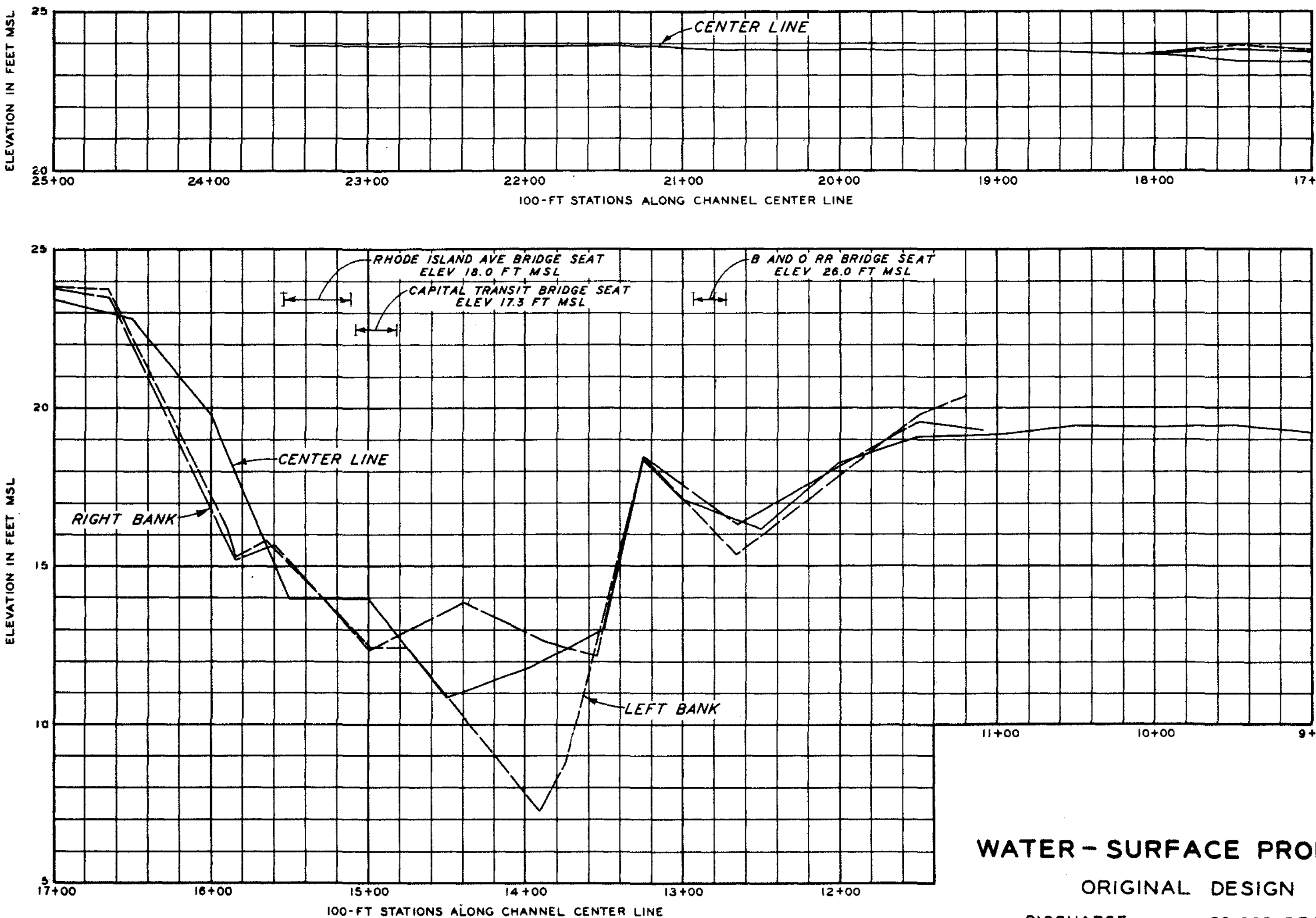

PLATE 1

PLATE 2




DETAILS OF CONCRETE CHANNEL

ORIGINAL DESIGN

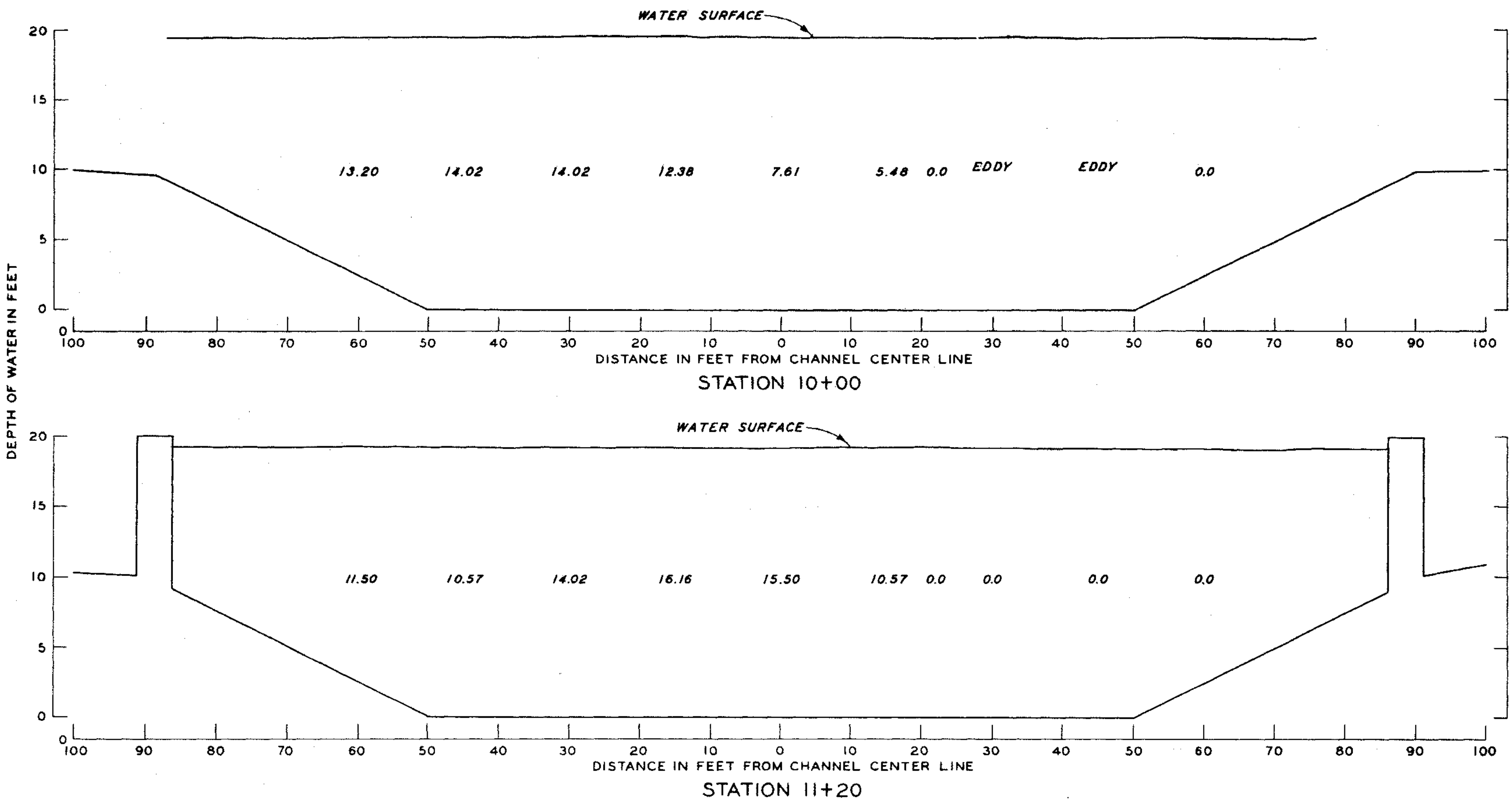



## WATER - SURFACE PROFILES

ORIGINAL DESIGN

DISCHARGE 20,000 CFS

TAILWATER ELEV 19.4 FT MSL

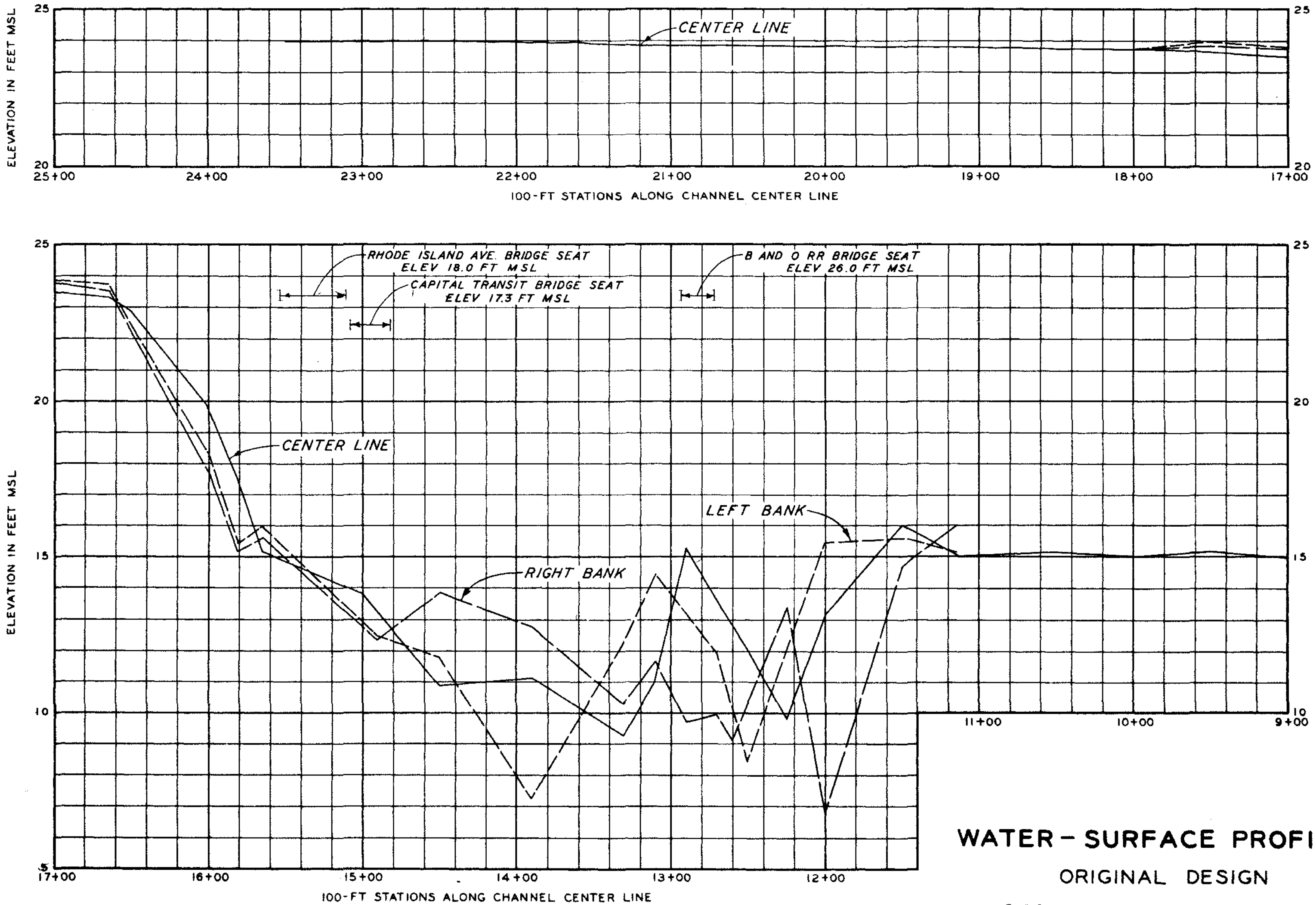



NOTE: VELOCITY IN FEET PER SECOND (PROTOTYPE).

# VELOCITY OBSERVATIONS

## ORIGINAL DESIGN

DISCHARGE 20,000 CFS
TAILWATER ELEV 19.4 FT MSL

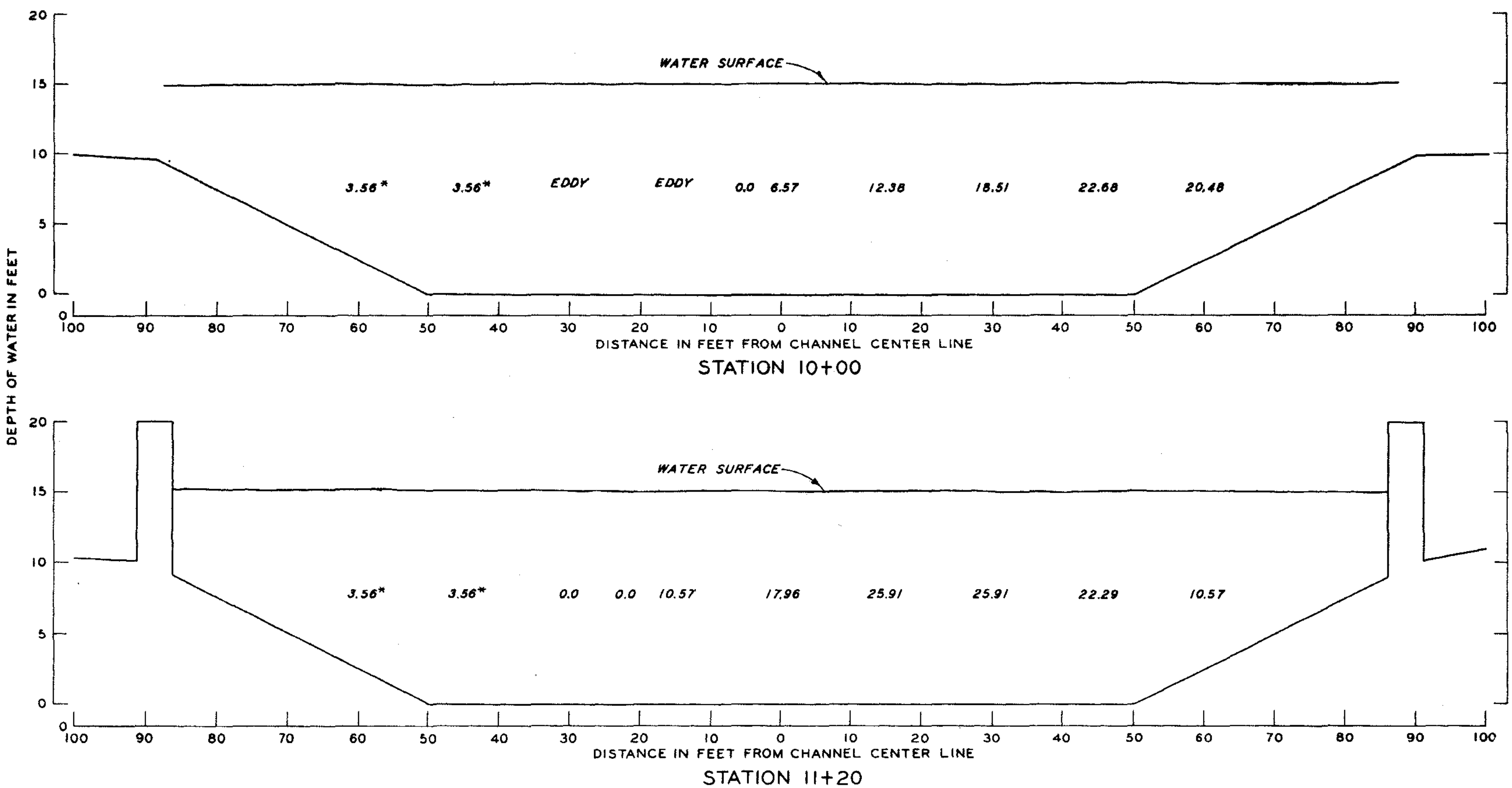



## WATER – SURFACE PROFILES

ORIGINAL DESIGN

DISCHARGE 20,000 CFS

TAILWATER ELEV 15.4 FT MSL




NOTE: VELOCITY IN FEET PER SECOND (PROTOTYPE).

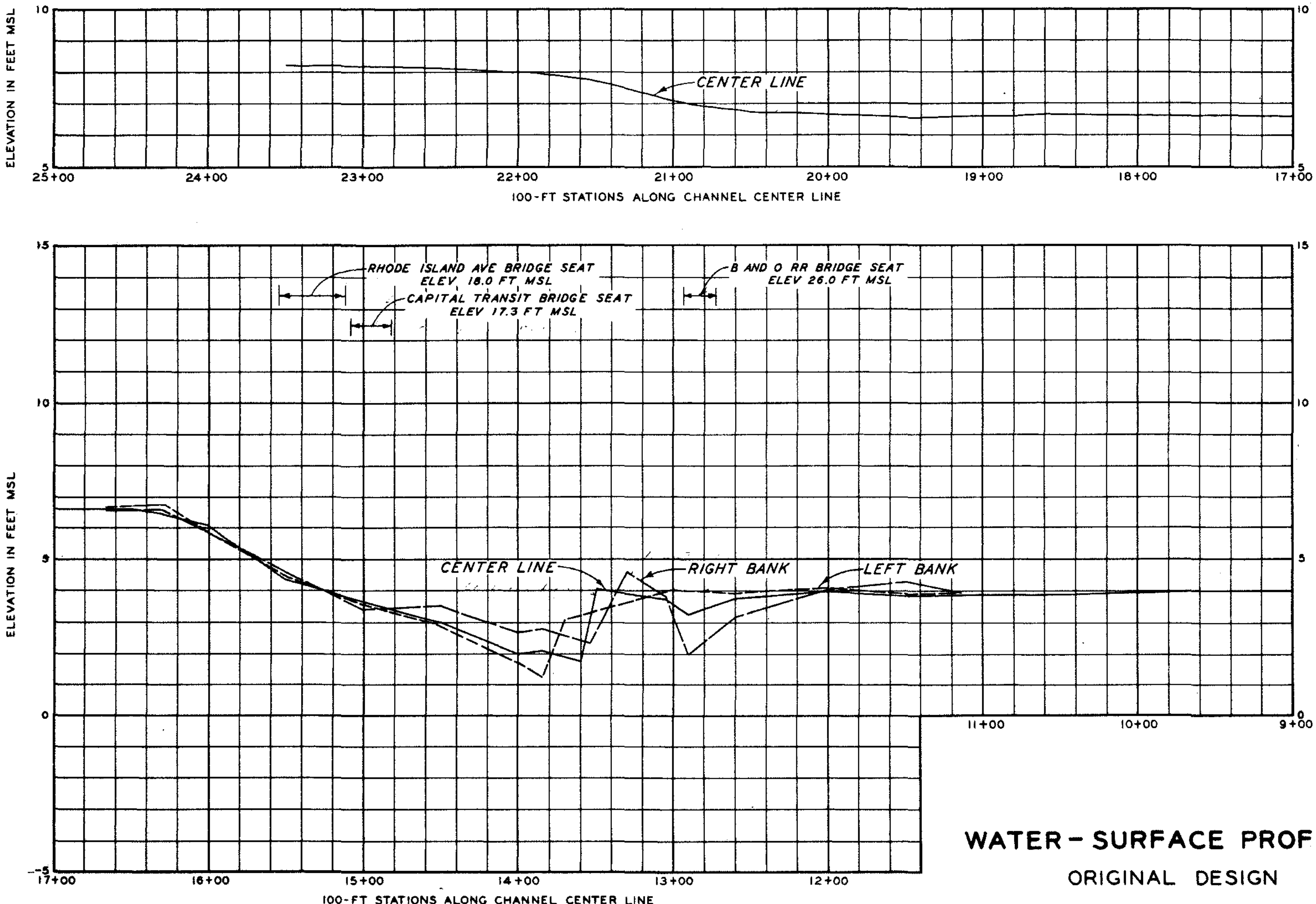
* UPSTREAM CURRENTS

# VELOCITY OBSERVATIONS

## ORIGINAL DESIGN

DISCHARGE 20,000 CFS

TAILWATER ELEV 15.4 FT MSL

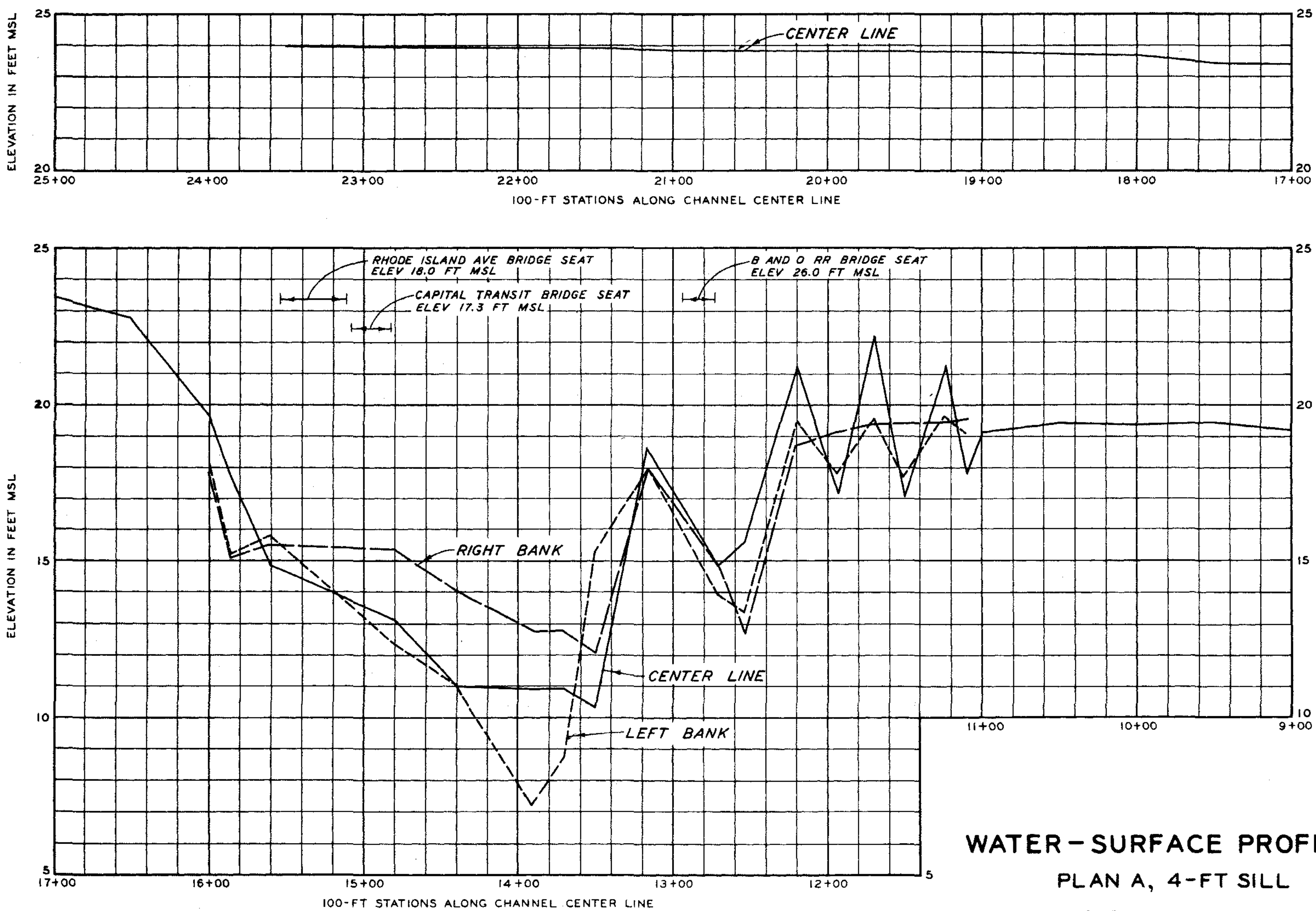



**WATER-SURFACE PROFILES**

ORIGINAL DESIGN

DISCHARGE 2000 CFS

TAILWATER ELEV 4.0 FT MSL

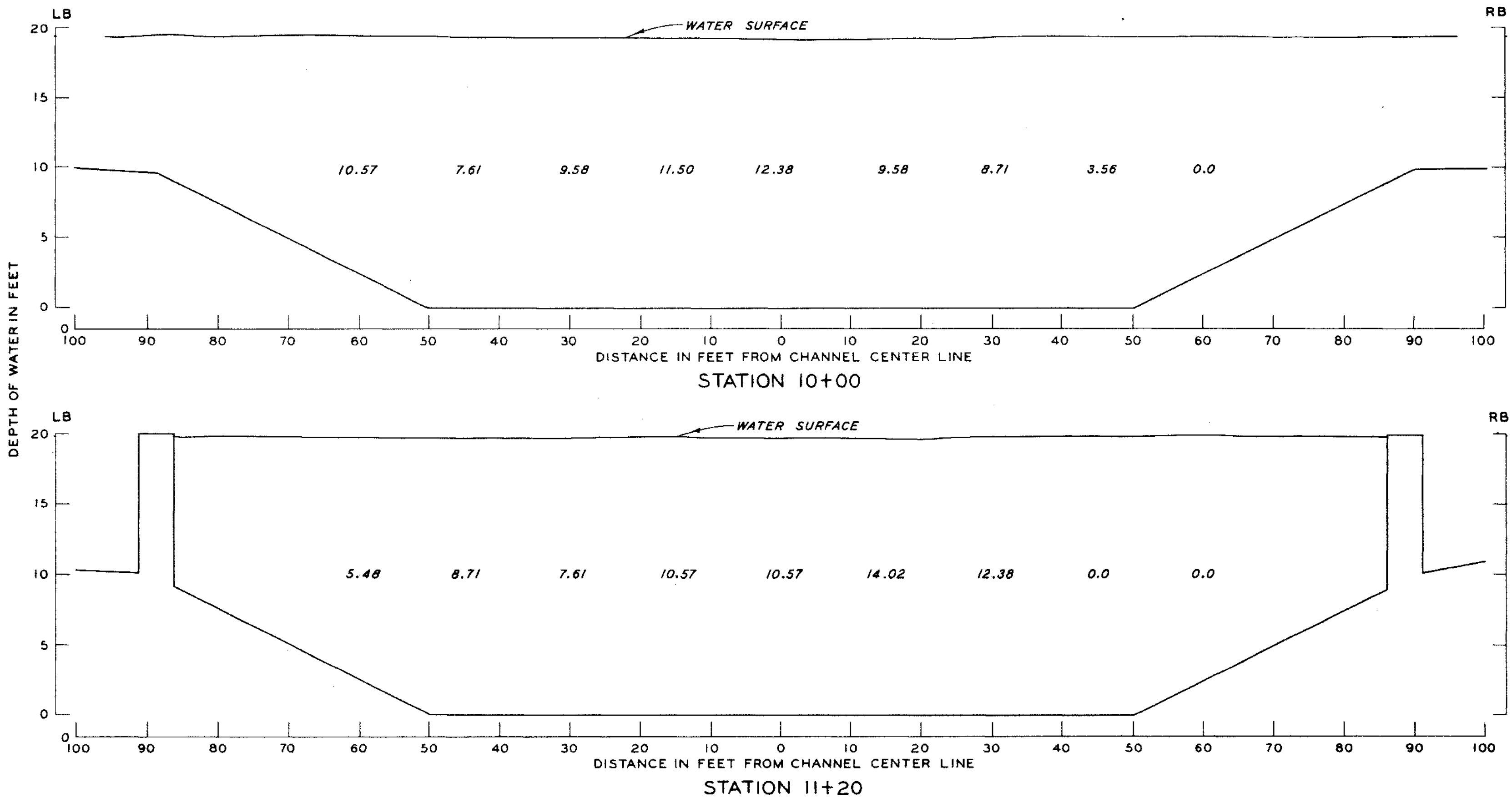



# WATER-SURFACE PROFILES

## PLAN A, 4-FT SILL

DISCHARGE 20,000 CFS

TAILWATER ELEV 19.4 FT MSL



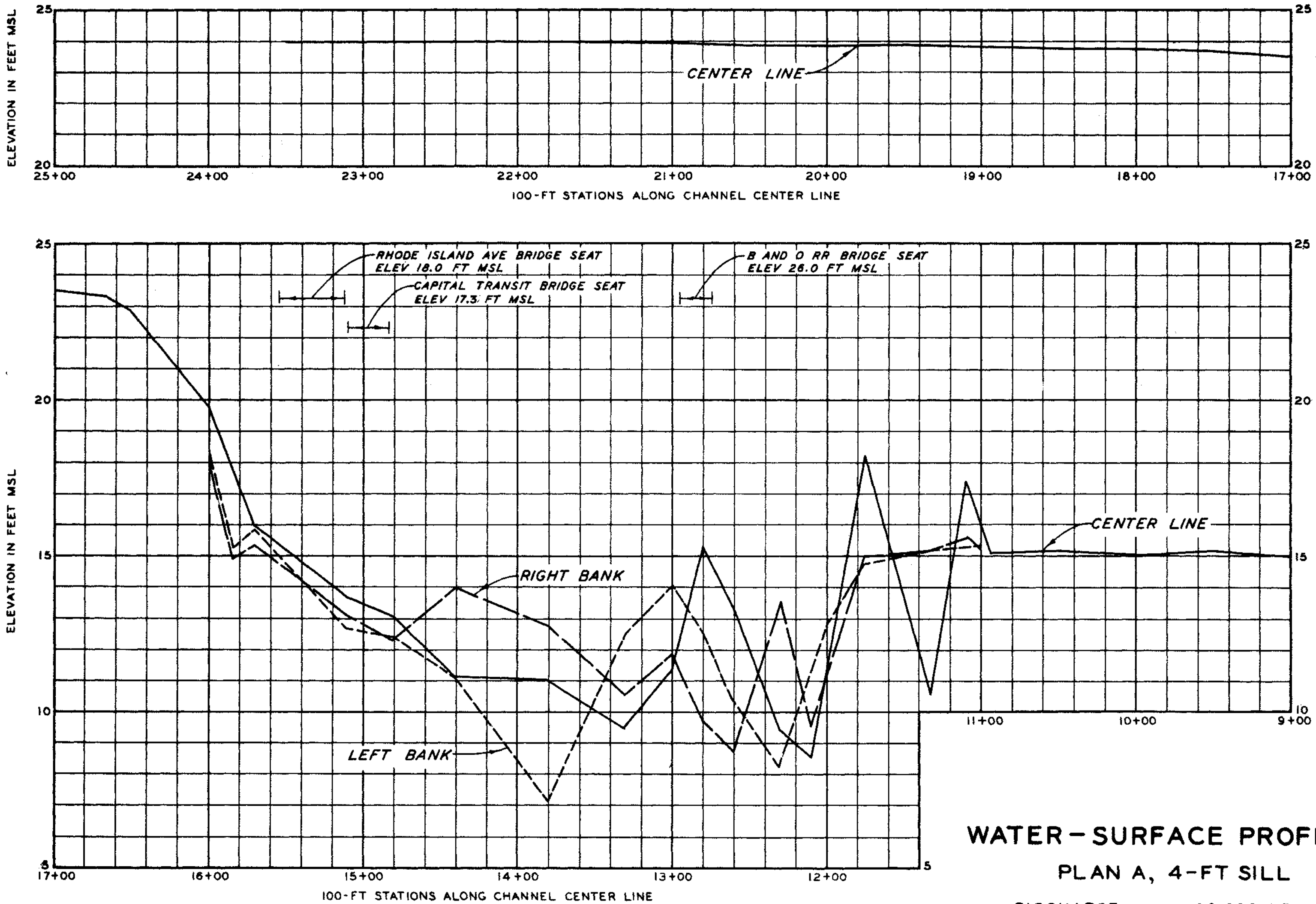

NOTE: VELOCITY IN FT PER SECOND (PROTOTYPE)

## VELOCITY OBSERVATIONS

### PLAN A, 4-FT SILL

DISCHARGE 20,000 CFS
TAILWATER ELEV 19.4 FT MSL

PLATE 10

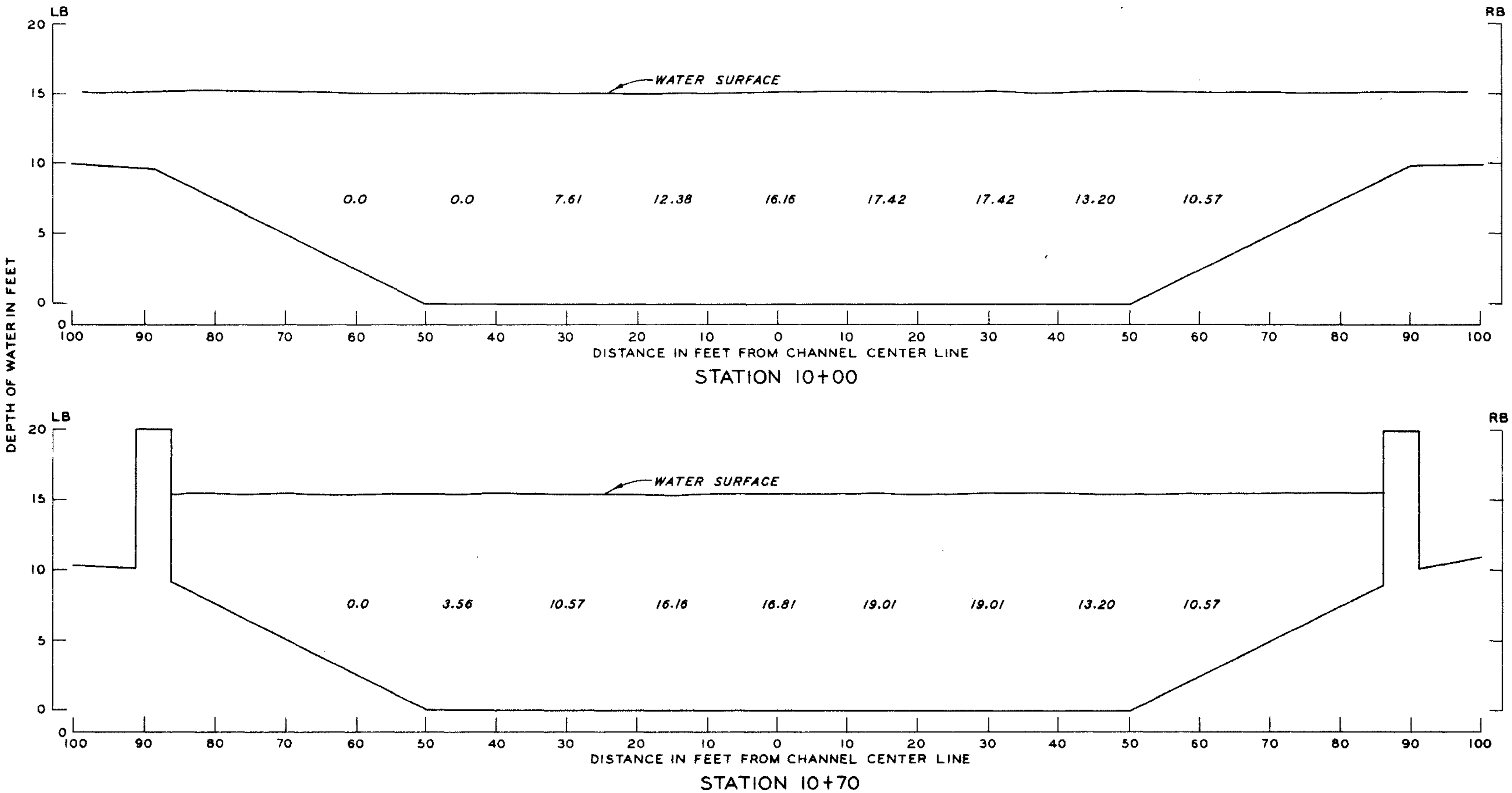



WATER-SURFACE PROFILES

PLAN A, 4-FT SILL

DISCHARGE 20,000 CFS

TAILWATER ELEV 15.4 FT MSL



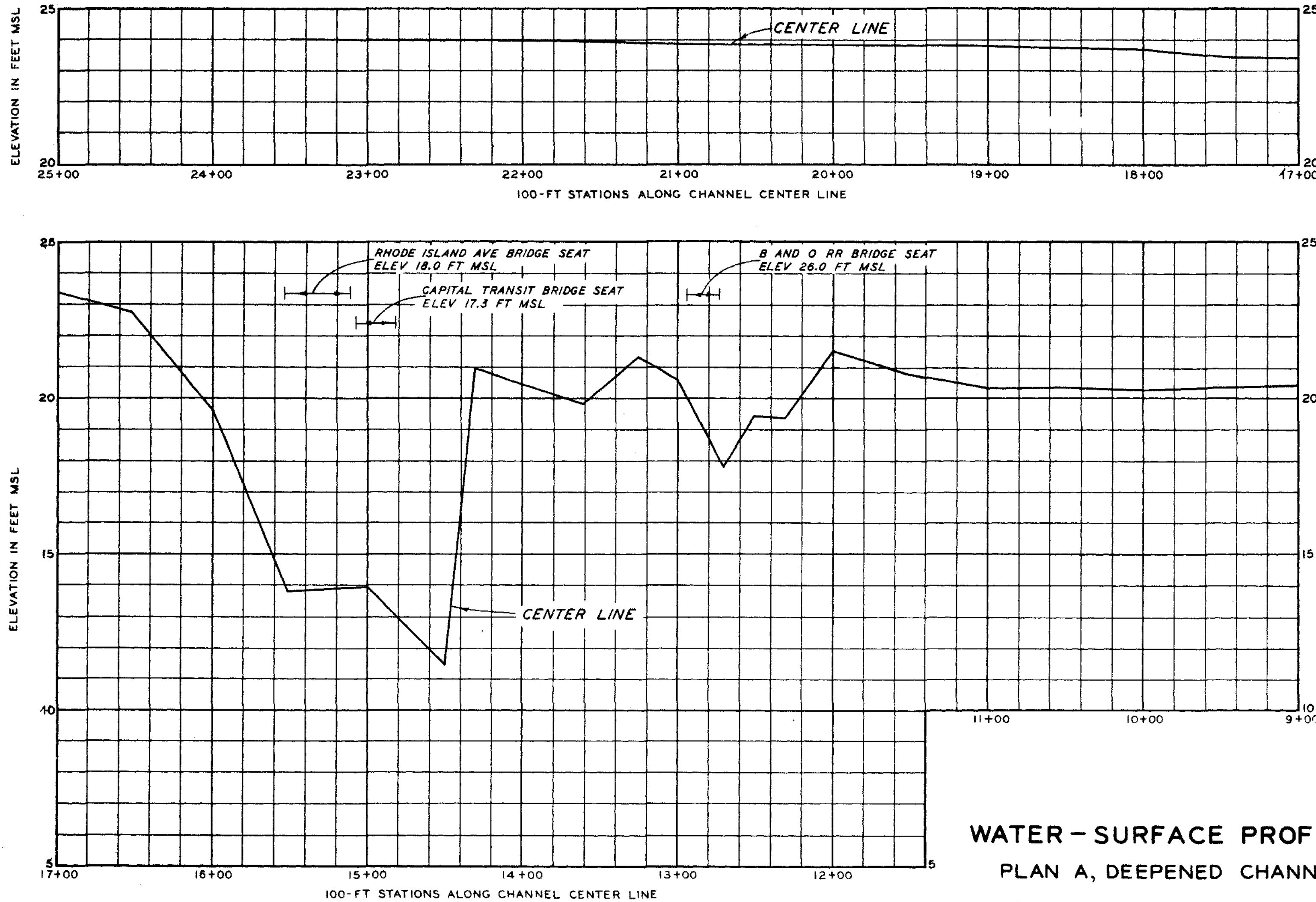

NOTE: VELOCITY IN FT PER SECOND (PROTOTYPE)

# VELOCITY OBSERVATIONS

## PLAN A, 4-FT SILL

DISCHARGE 20,000 CFS
TAILWATER ELEV 15.4 FT MSL

PLATE 12

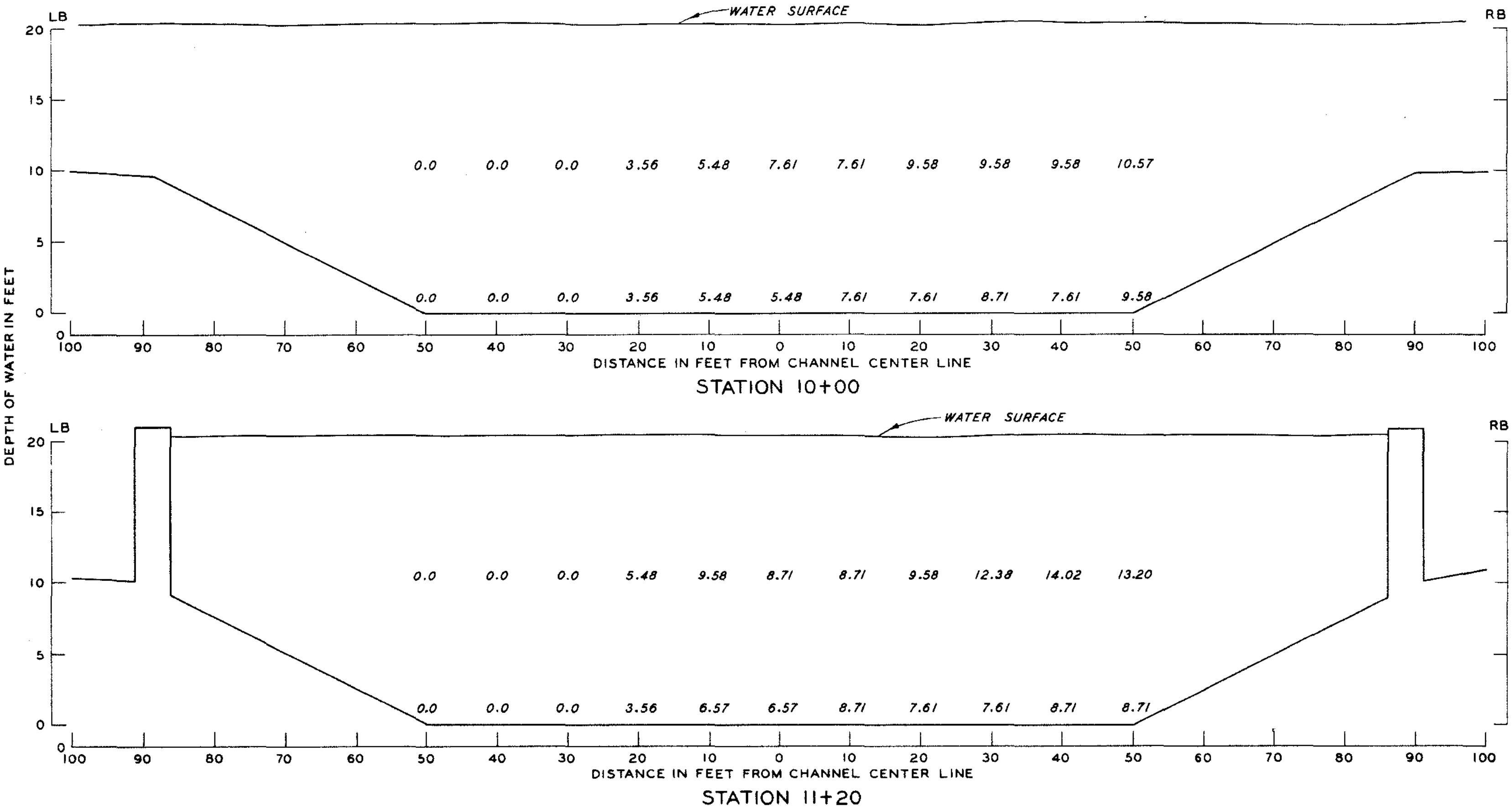



## WATER-SURFACE PROFILES

PLAN A, DEEPENED CHANNEL

DISCHARGE 20,000 CFS

TAILWATER ELEV 20.4 FT MSL




NOTE: VELOCITY IN FT PER SECOND (PROTOTYPE)

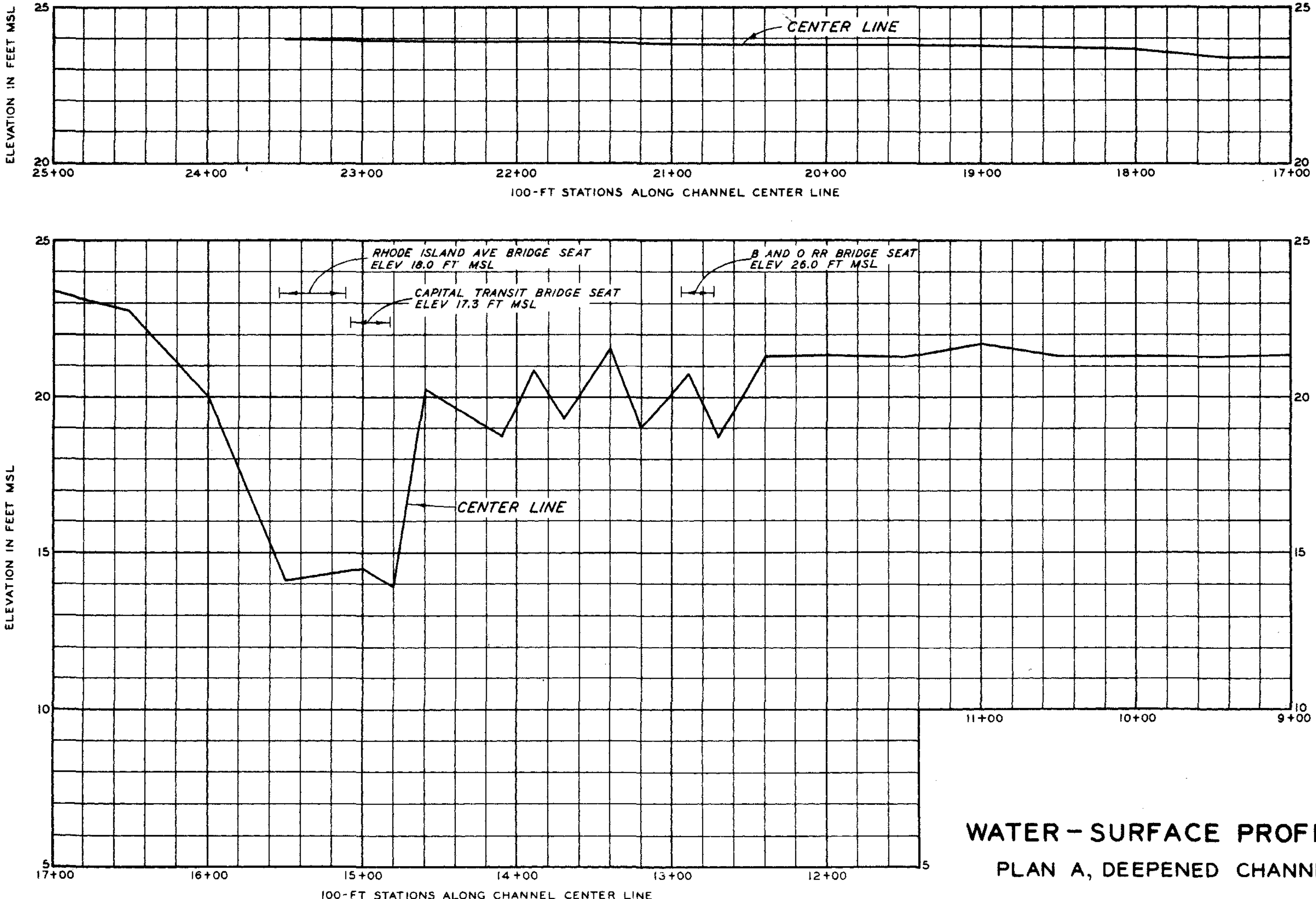
# VELOCITY OBSERVATIONS

## PLAN A, DEEPENED CHANNEL

DISCHARGE 20,000 CFS

TAILWATER ELEV 20.4 FT MSL

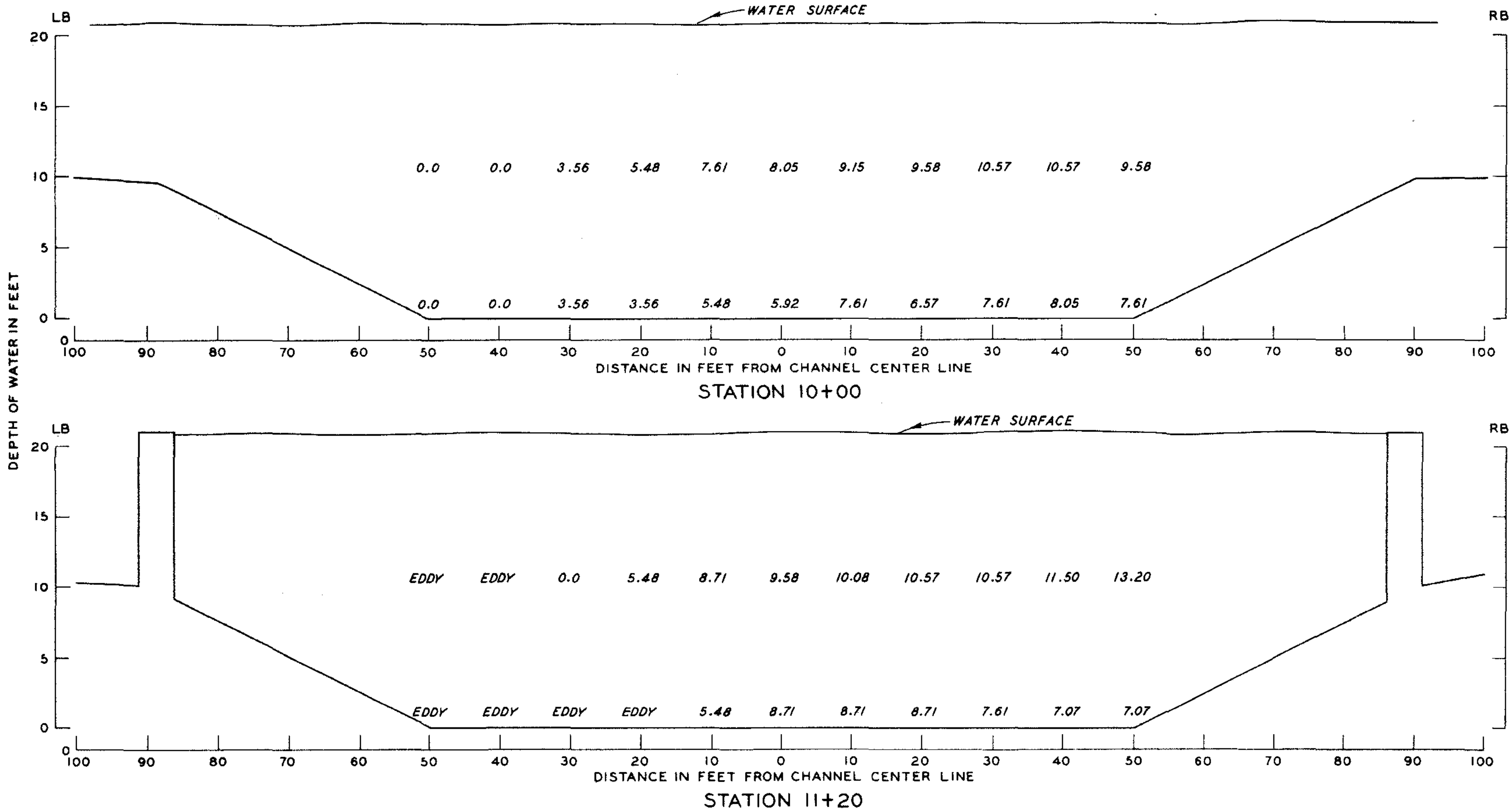
PLATE 14




# WATER – SURFACE PROFILES

## PLAN A, DEEPENED CHANNEL

DISCHARGE 20,000 CFS
TAILWATER ELEV 21.7 FT MSL



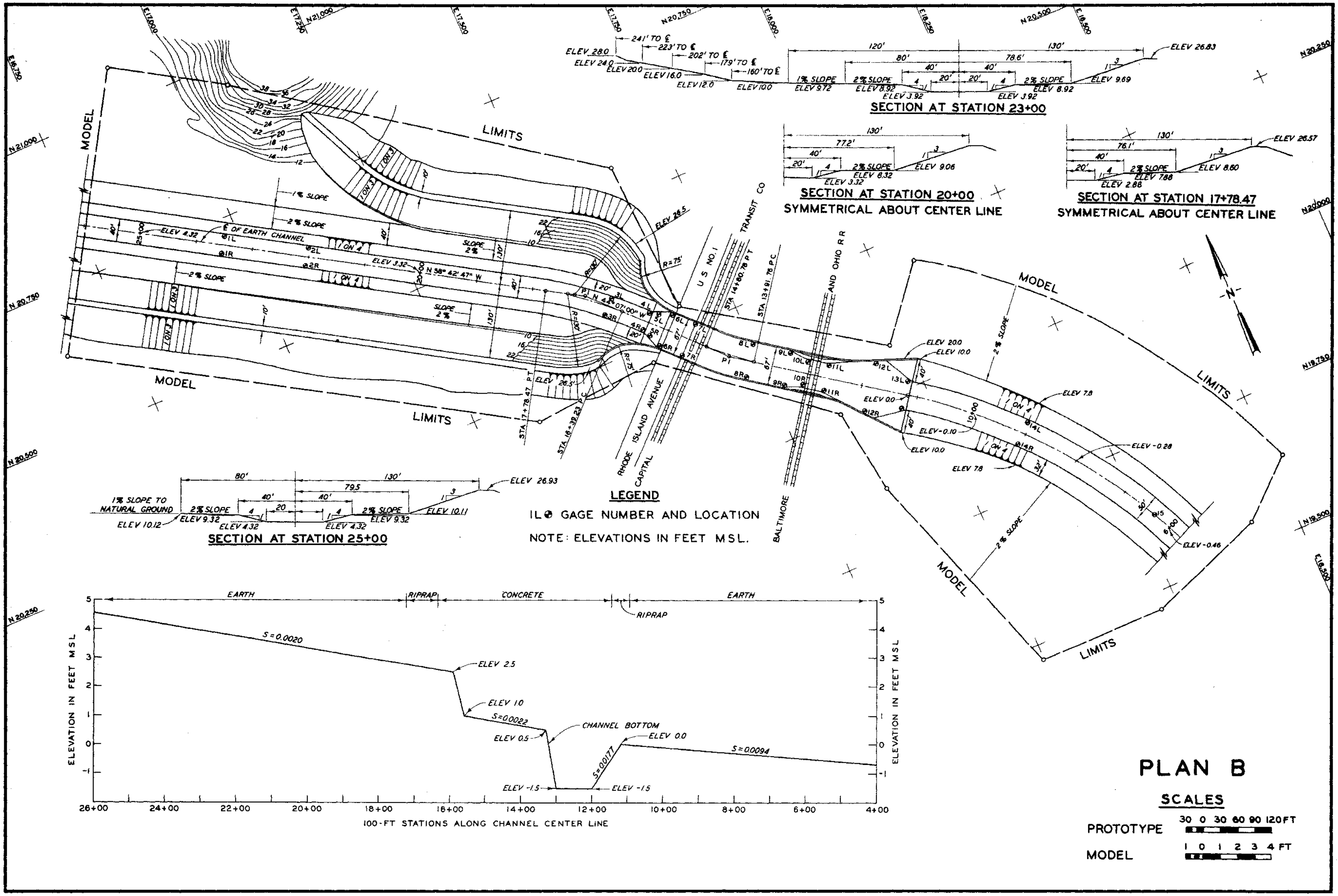

NOTE: VELOCITY IN FT PER SECOND (PROTOTYPE)

# VELOCITY OBSERVATIONS

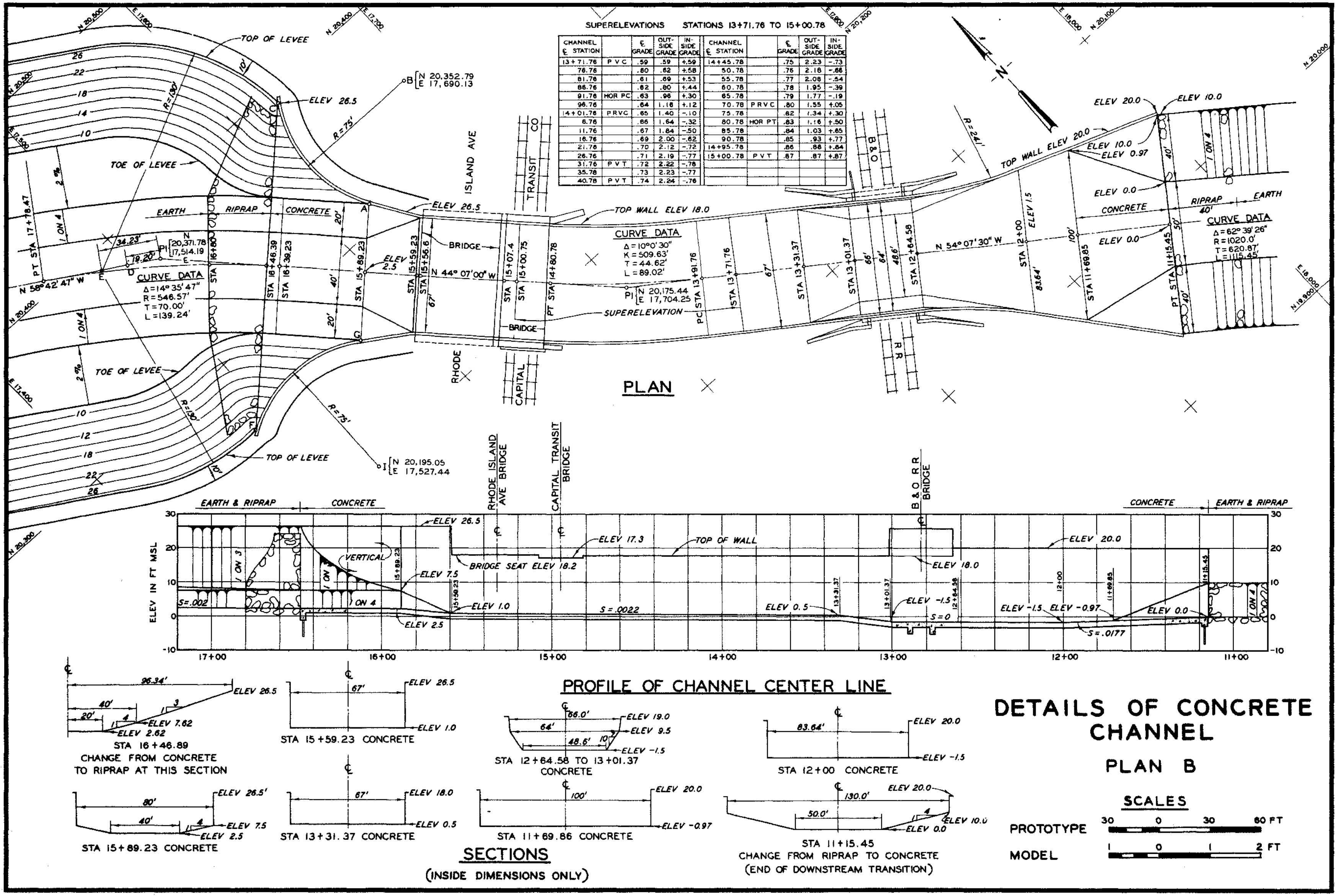
## PLAN A, DEEPENED CHANNEL

DISCHARGE 20,000 CFS
TAILWATER ELEV 21.7 FT MSL

PLATE 16



SECTION AT STATION 23+00
SECTION AT STATION 20+00
SYMMETRICAL ABOUT CENTER LINE
SECTION AT STATION 17+78.47
SYMMETRICAL ABOUT CENTER LINE
SECTION AT STATION 25+00
LEGEND
1L ⊗ GAGE NUMBER AND LOCATION
NOTE: ELEVATIONS IN FEET MSL.
MODEL
LIMITS
US NO. 1
TRANSIT CO
BALTIMORE AND OHIO R R
RHODE ISLAND AVENUE
CAPITAL
℄ OF EARTH CHANNEL
N 58° 42' 47" W
EARTH
RIPRAP
CONCRETE
EARTH
RIPRAP
S=0.0020
ELEV 2.5
ELEV 1.0
S=0.0022
ELEV 0.5
CHANNEL BOTTOM
ELEV 0.0
S=0.0094
ELEV -1.5
ELEV -1.5
ELEVATION IN FEET MSL
100-FT STATIONS ALONG CHANNEL CENTER LINE
26+00
24+00
22+00
20+00
18+00
16+00
14+00
12+00
10+00
8+00
6+00
4+00
PLAN B
SCALES
PROTOTYPE
30 0 30 60 90 120 FT
MODEL
1 0 1 2 3 4 FT



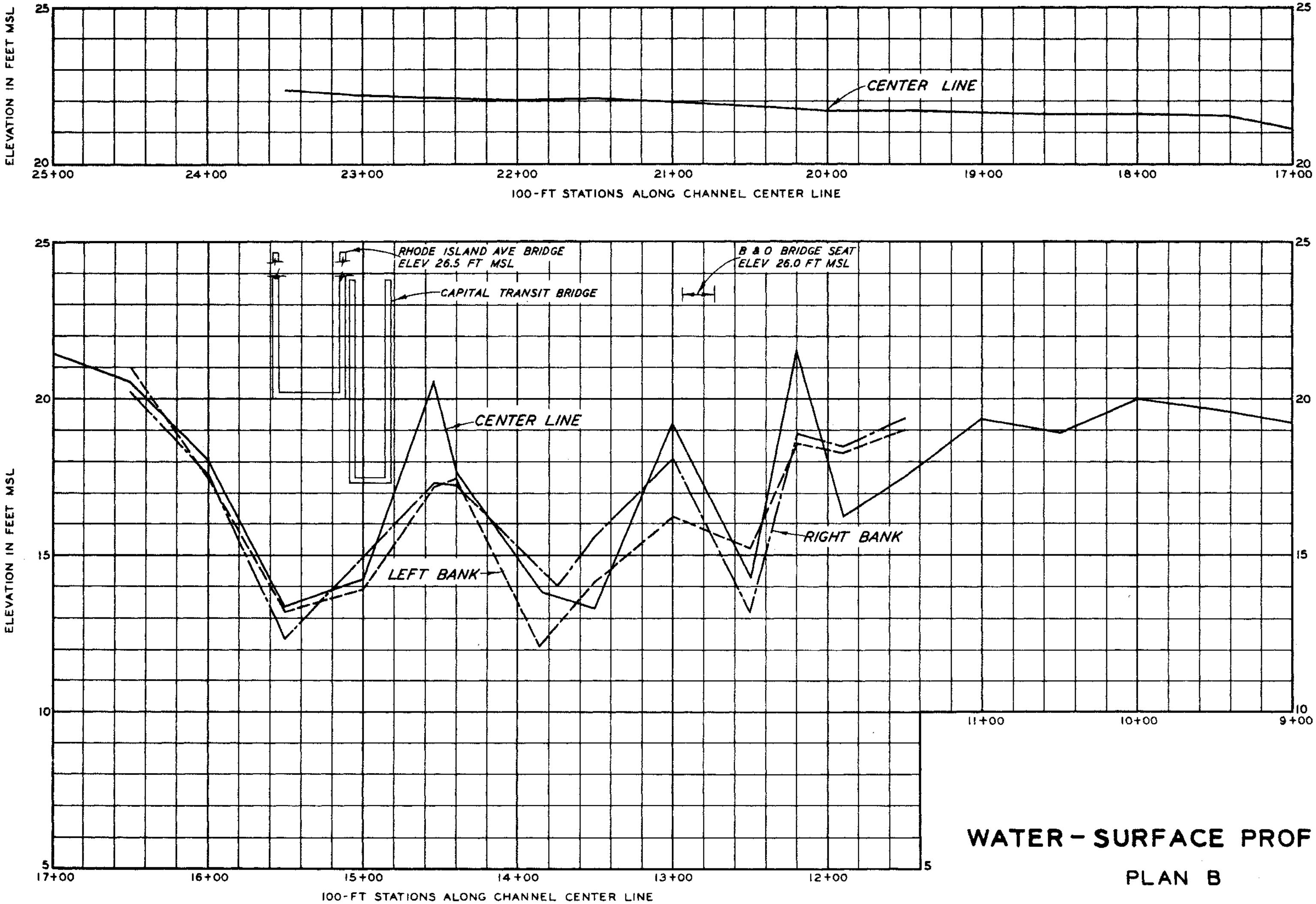

SUPERELEVATIONS STATIONS 13+71.76 TO 15+00.78

| CHANNEL ℄ STATION | | ℄ GRADE | OUT-SIDE GRADE | IN-SIDE GRADE | CHANNEL ℄ STATION | | ℄ GRADE | OUT-SIDE GRADE | IN-SIDE GRADE |
|---|---|---|---|---|---|---|---|---|---|
| 13+71.76 | P V C | .59 | .59 | +.59 | 14+45.78 | | .75 | 2.23 | -.73 |
| 76.76 | | .60 | .62 | +.58 | 50.78 | | .76 | 2.18 | -.66 |
| 81.76 | | .61 | .69 | +.53 | 55.78 | | .77 | 2.08 | -.54 |
| 86.76 | | .62 | .80 | +.44 | 60.78 | | .78 | 1.95 | -.39 |
| 91.76 | HOR PC | .63 | .96 | +.30 | 65.78 | | .79 | 1.77 | -.19 |
| 96.76 | | .64 | 1.16 | +.12 | 70.78 | P R V C | .80 | 1.55 | +.05 |
| 14+01.76 | P R V C | .65 | 1.40 | -.10 | 75.78 | | .82 | 1.34 | +.30 |
| 6.76 | | .66 | 1.64 | -.32 | 80.78 | HOR PT | .83 | 1.16 | +.50 |
| 11.76 | | .67 | 1.84 | -.50 | 85.78 | | .84 | 1.03 | +.65 |
| 16.76 | | .69 | 2.00 | -.62 | 90.78 | | .85 | .93 | +.77 |
| 21.76 | | .70 | 2.12 | -.72 | 14+95.78 | | .86 | .88 | +.84 |
| 26.76 | | .71 | 2.19 | -.77 | 15+00.78 | P V T | .87 | .87 | +.87 |
| 31.76 | P V T | .72 | 2.22 | -.78 | | | | | |
| 35.78 | | .73 | 2.23 | -.77 | | | | | |
| 40.78 | P V T | .74 | 2.24 | -.76 | | | | | |

# DETAILS OF CONCRETE CHANNEL

## PLAN B

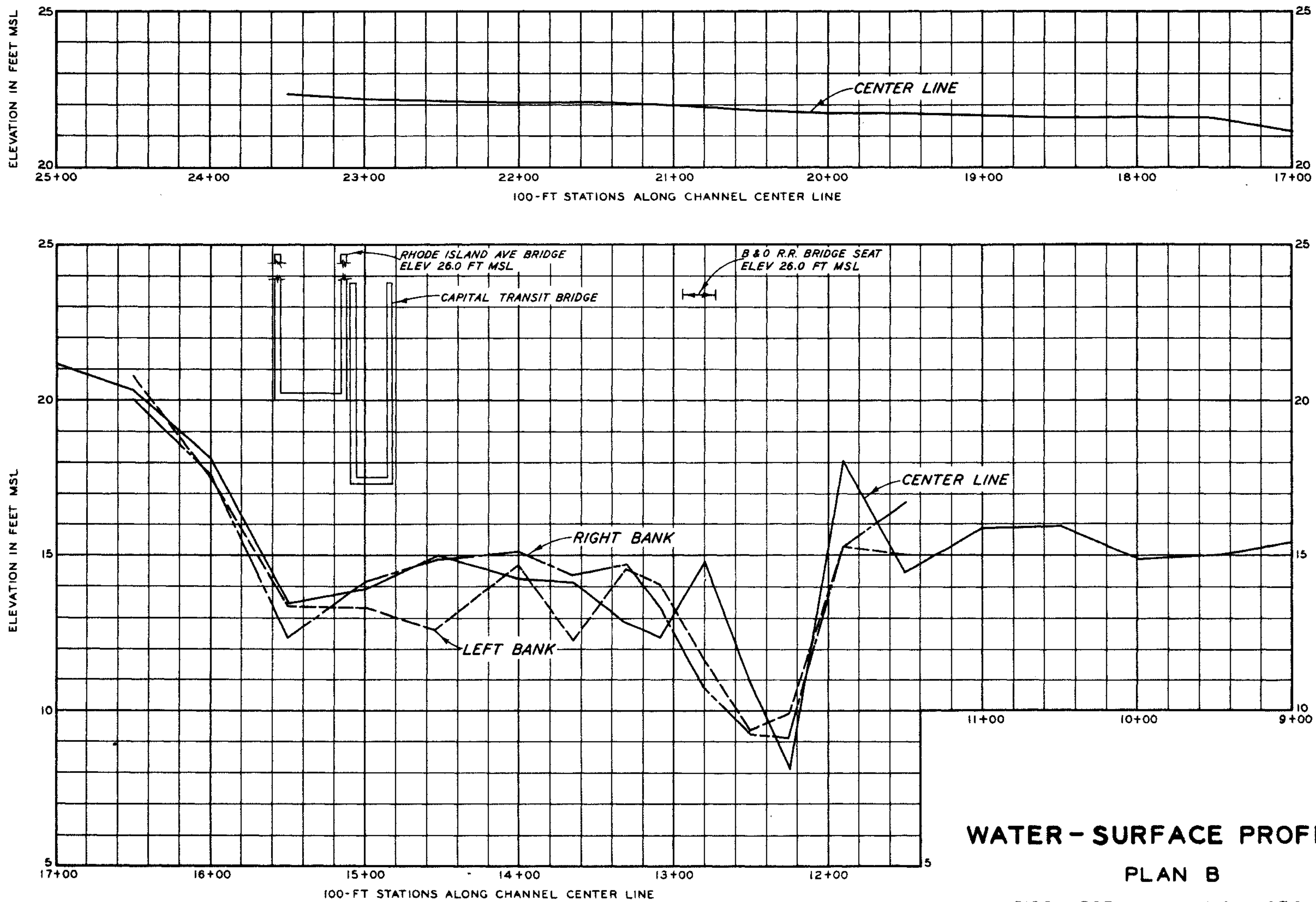
PLATE 17




# WATER – SURFACE PROFILES

## PLAN B

DISCHARGE 20,000 CFS
TAILWATER ELEV 19.4 FT MSL



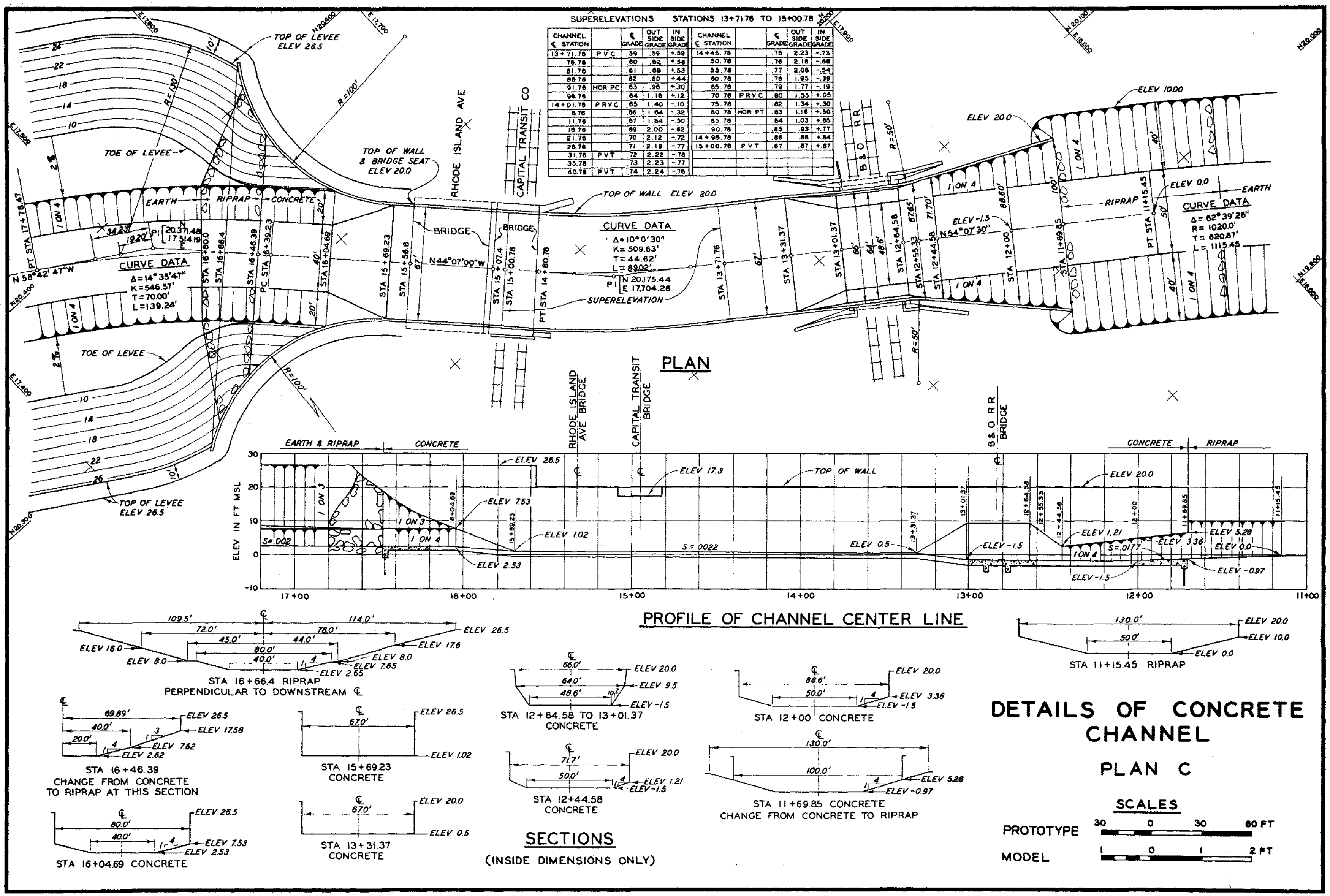

# WATER – SURFACE PROFILES

## PLAN B

DISCHARGE 20,000 CFS

TAILWATER ELEV 15.4 FT MSL

PLATE 20

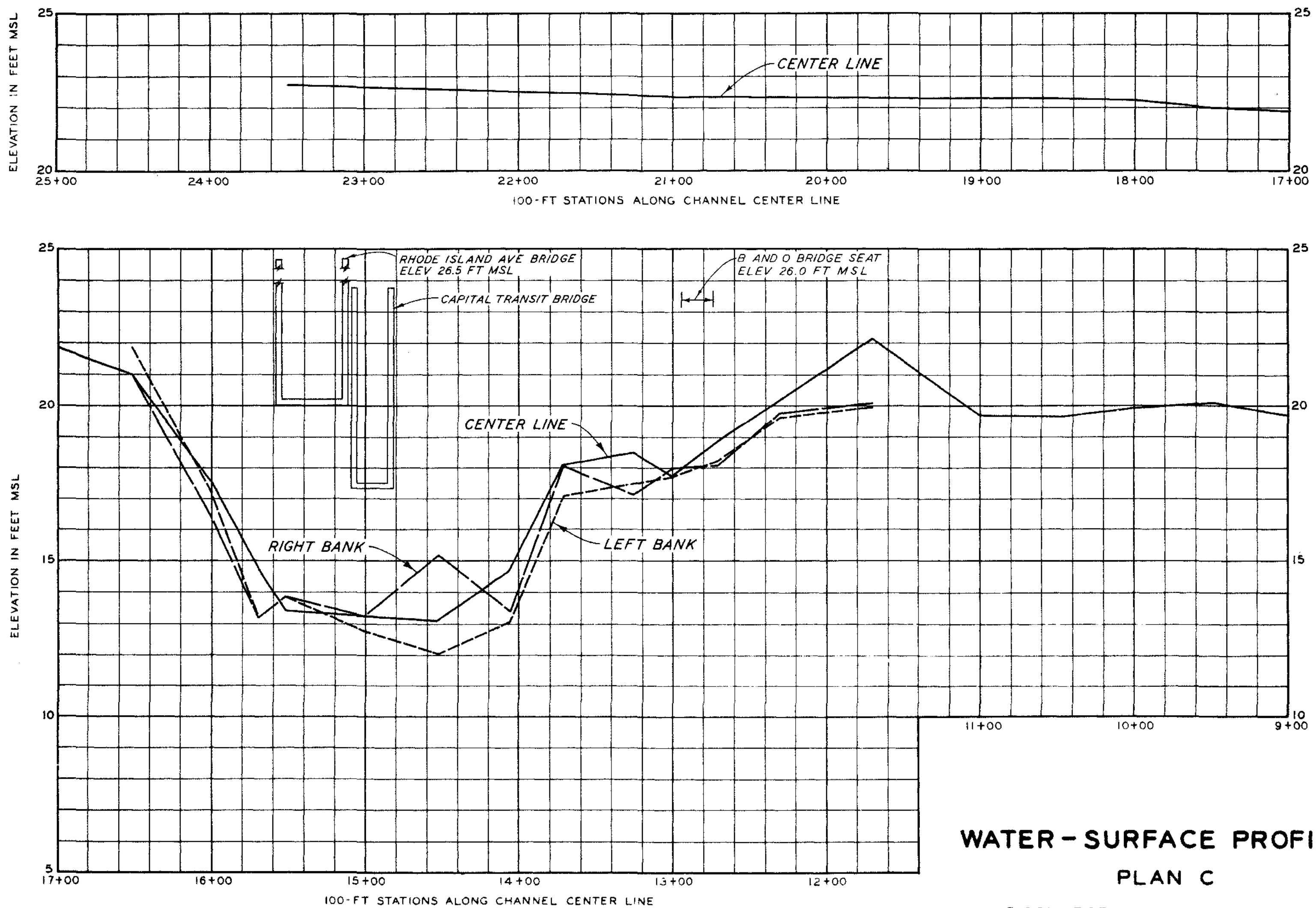



SUPERELEVATIONS STATIONS 13+71.76 TO 15+00.78

| CHANNEL ℄ STATION | | ℄ GRADE | OUT SIDE GRADE | IN SIDE GRADE | CHANNEL ℄ STATION | | ℄ GRADE | OUT SIDE GRADE | IN SIDE GRADE |
|---|---|---|---|---|---|---|---|---|---|
| 13 + 71.76 | P V C | .59 | .59 | +.59 | 14 + 45.78 | | .75 | 2.23 | -.73 |
| 76.76 | | .60 | .62 | +.58 | 50.78 | | .76 | 2.18 | -.66 |
| 81.76 | | .61 | .69 | +.53 | 55.78 | | .77 | 2.08 | -.54 |
| 86.76 | | .62 | .80 | +.44 | 60.78 | | .78 | 1.95 | -.39 |
| 91.76 | HOR PC | .63 | .96 | +.30 | 65.78 | | .79 | 1.77 | -.19 |
| 96.76 | | .64 | 1.16 | +.12 | 70.78 | P R V C | .80 | 1.55 | +.05 |
| 14 + 01.76 | P R V C | .65 | 1.40 | -.10 | 75.78 | | .82 | 1.34 | +.30 |
| 6.76 | | .66 | 1.64 | -.32 | 80.78 | HOR PT | .83 | 1.16 | +.50 |
| 11.76 | | .67 | 1.84 | -.50 | 85.78 | | .84 | 1.03 | +.65 |
| 16.76 | | .69 | 2.00 | -.62 | 90.78 | | .85 | .93 | +.77 |
| 21.76 | | .70 | 2.12 | -.72 | 14 + 95.78 | | .86 | .88 | +.84 |
| 26.76 | | .71 | 2.19 | -.77 | 15 + 00.78 | P V T | .87 | .87 | +.87 |
| 31.76 | P V T | .72 | 2.22 | -.78 | | | | | |
| 35.78 | | .73 | 2.23 | -.77 | | | | | |
| 40.78 | P V T | .74 | 2.24 | -.76 | | | | | |

DETAILS OF CONCRETE CHANNEL

PLAN C

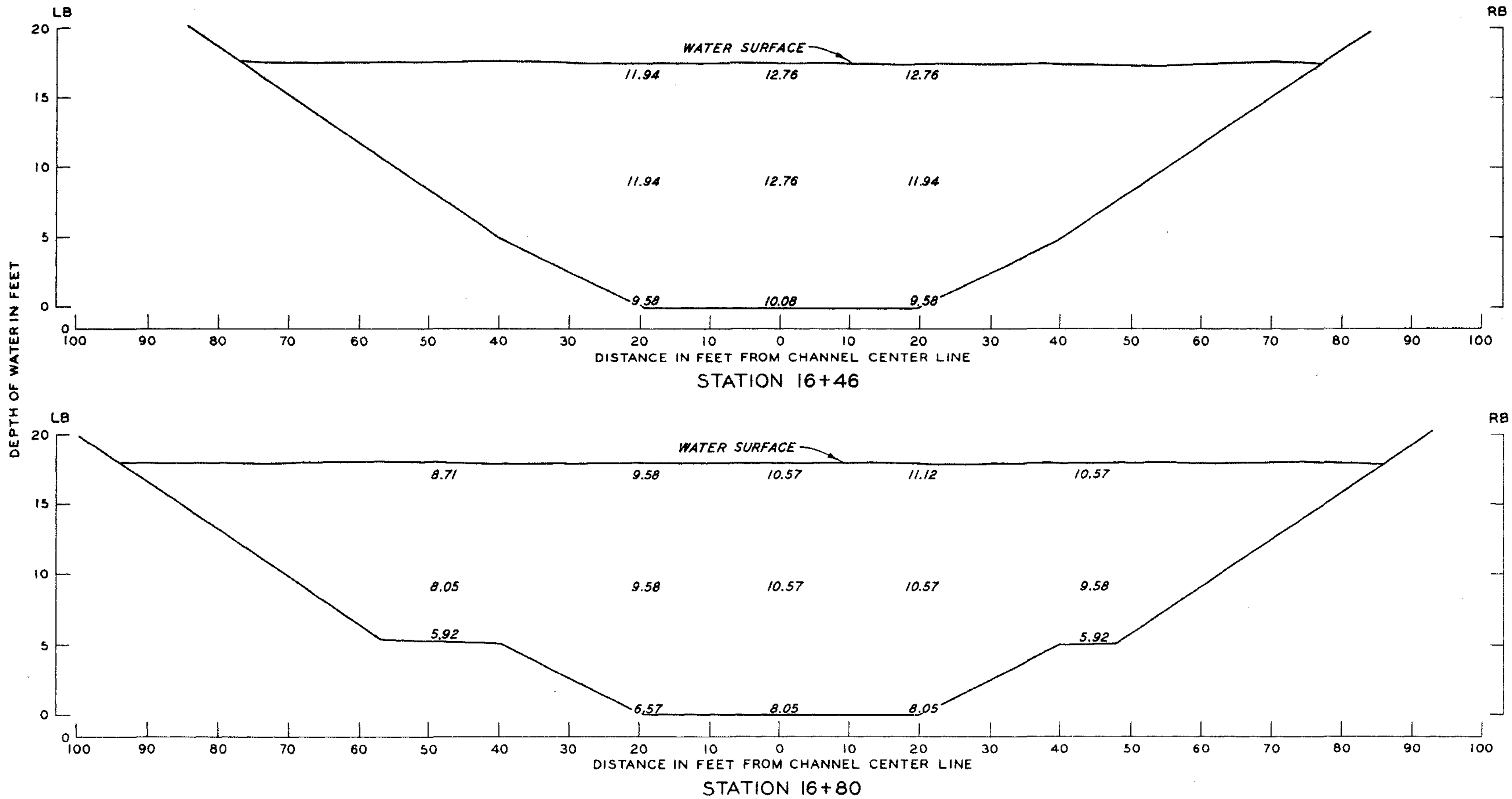



# WATER-SURFACE PROFILES

## PLAN C

DISCHARGE 20,000 CFS
TAILWATER ELEV 19.4 FT MSL

PLATE 21




NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

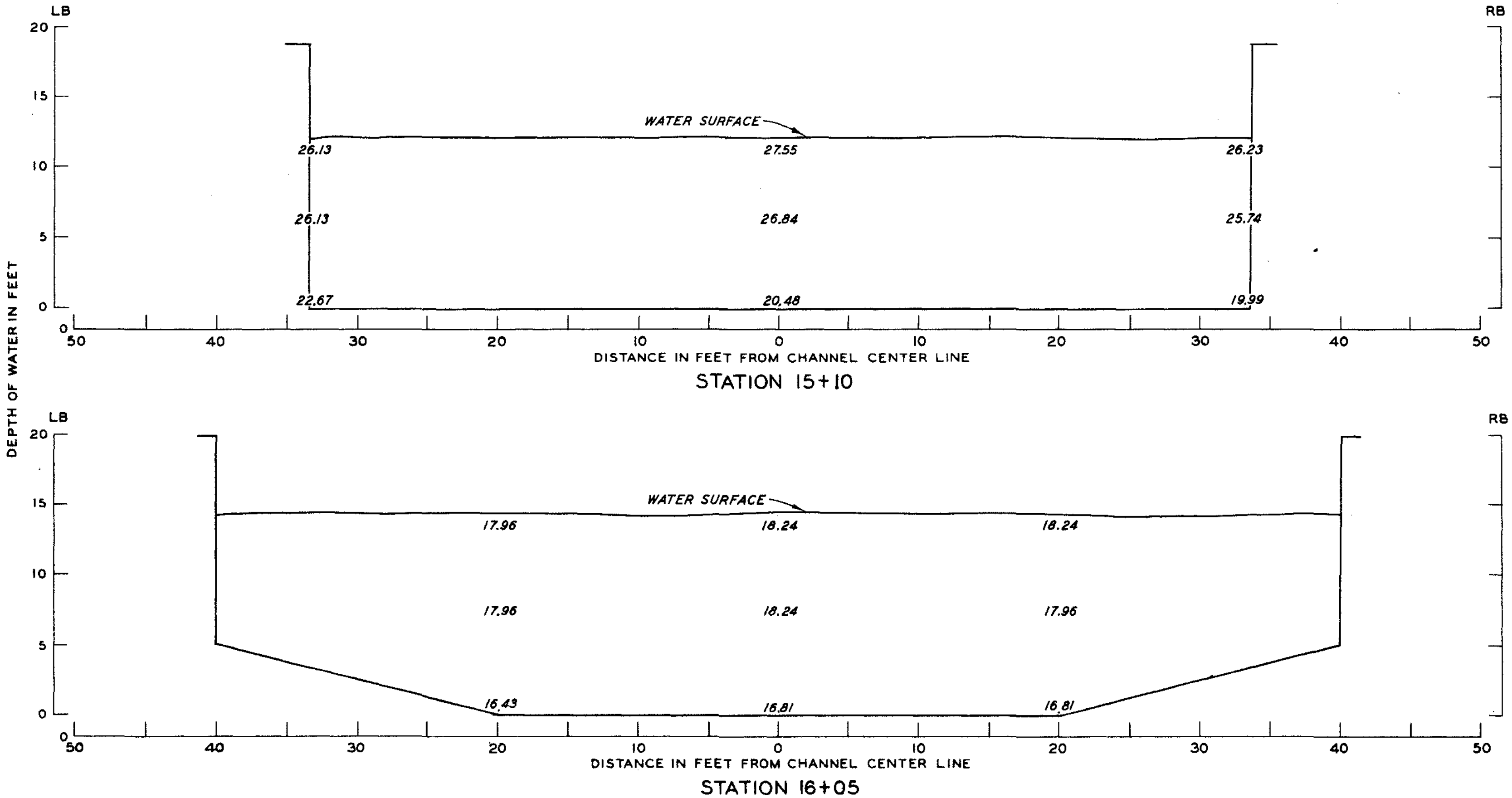
# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 20,000 CFS

TAILWATER ELEV 19.4 FT MSL

STATIONS 16+46 AND 16+80




NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

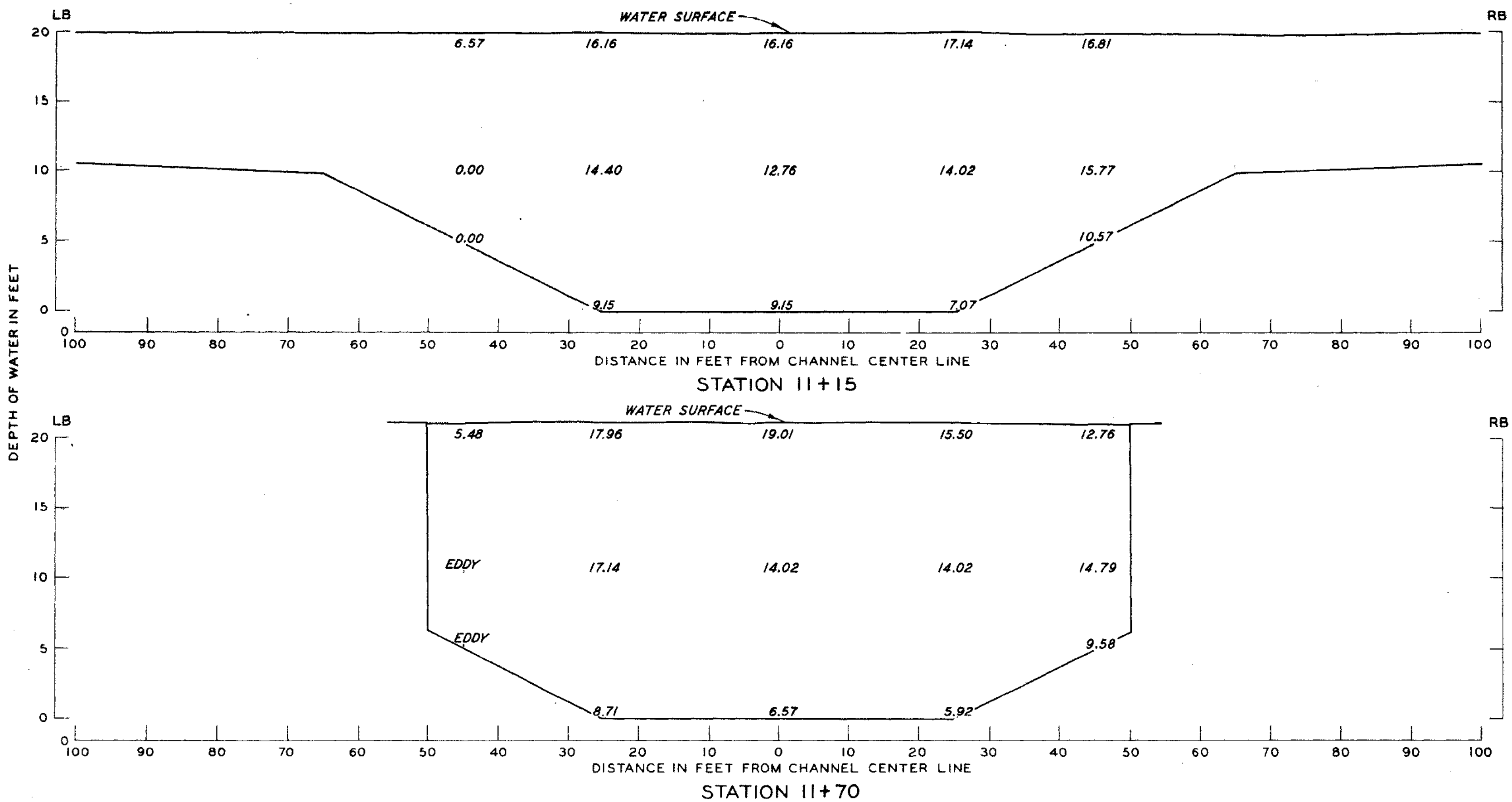
# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 20,000 CFS

TAILWATER ELEV 19.4 FT MSL

STATIONS 15+10 AND 16+05



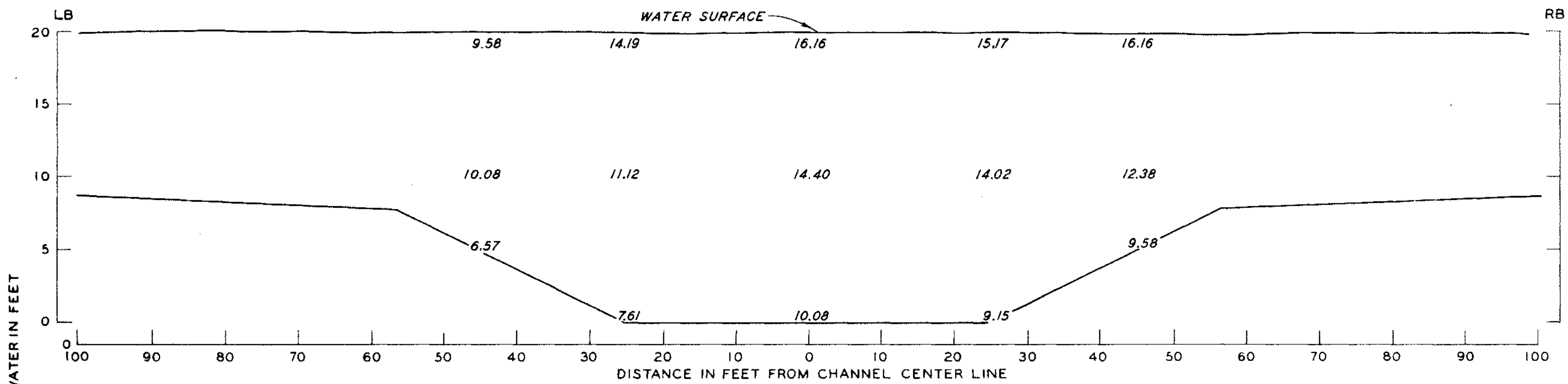

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

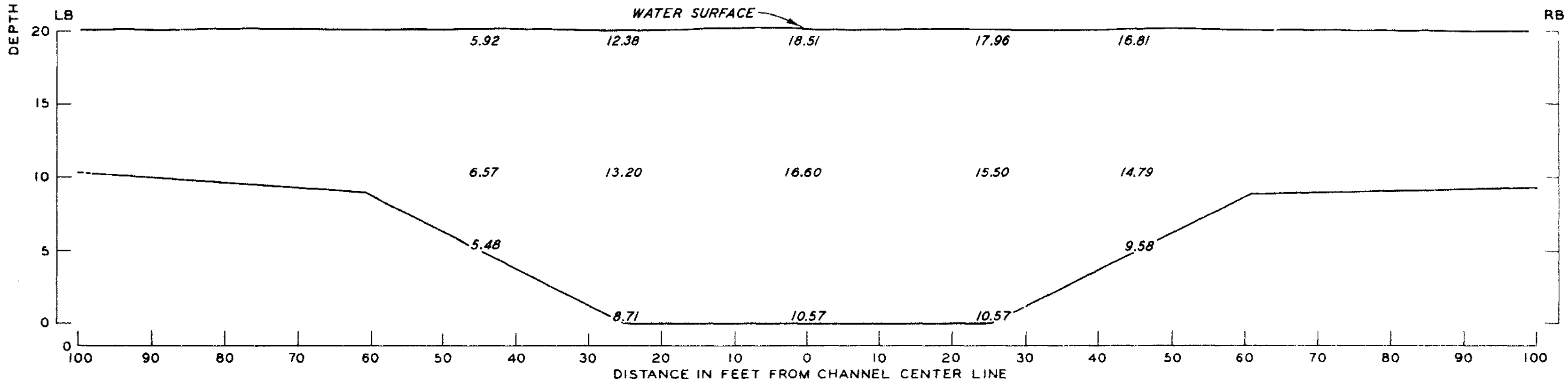
## PLAN C

| | |
|---|---|
| DISCHARGE | 20,000 CFS |
| TAILWATER ELEV | 19.4 FT MSL |

STATIONS 11+15 AND 11+70




STATION 9+00




STATION 10+00

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

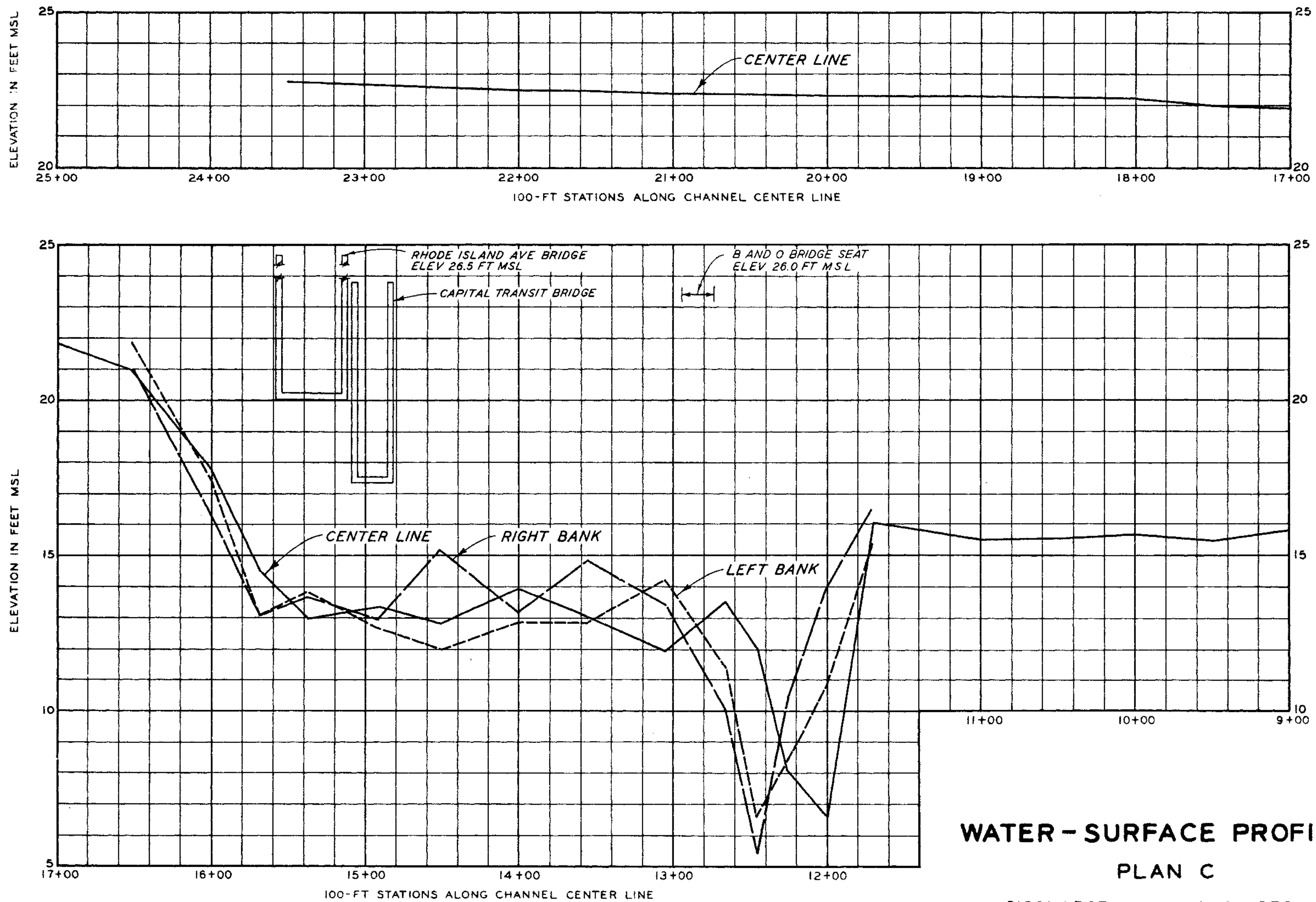
# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 20,000 CFS

TAILWATER ELEV 19.4 FT MSL

STATIONS 9+10 AND 10+00

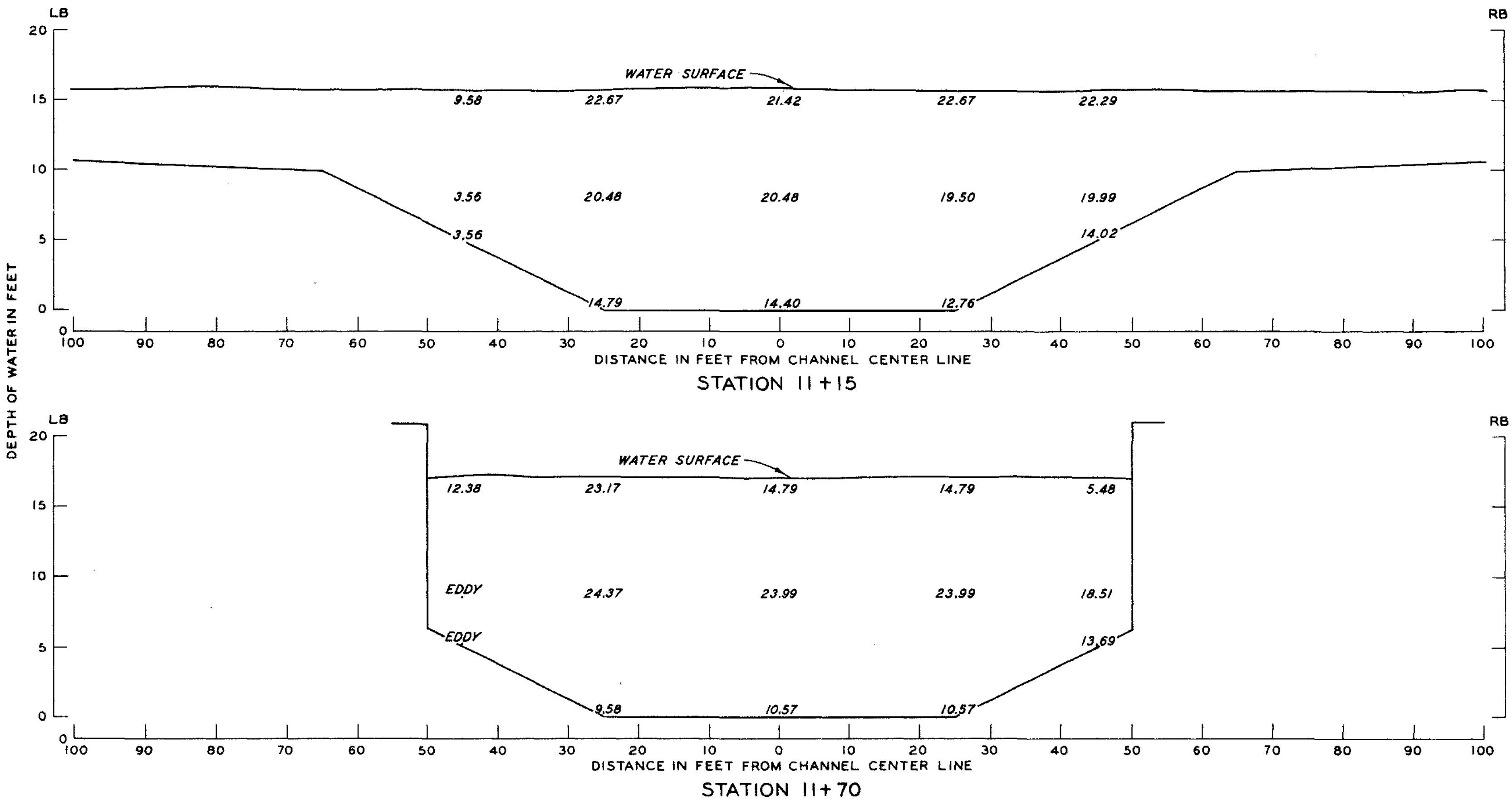



# WATER-SURFACE PROFILES

## PLAN C

DISCHARGE 20,000 CFS

TAILWATER ELEV 15.4 FT MSL

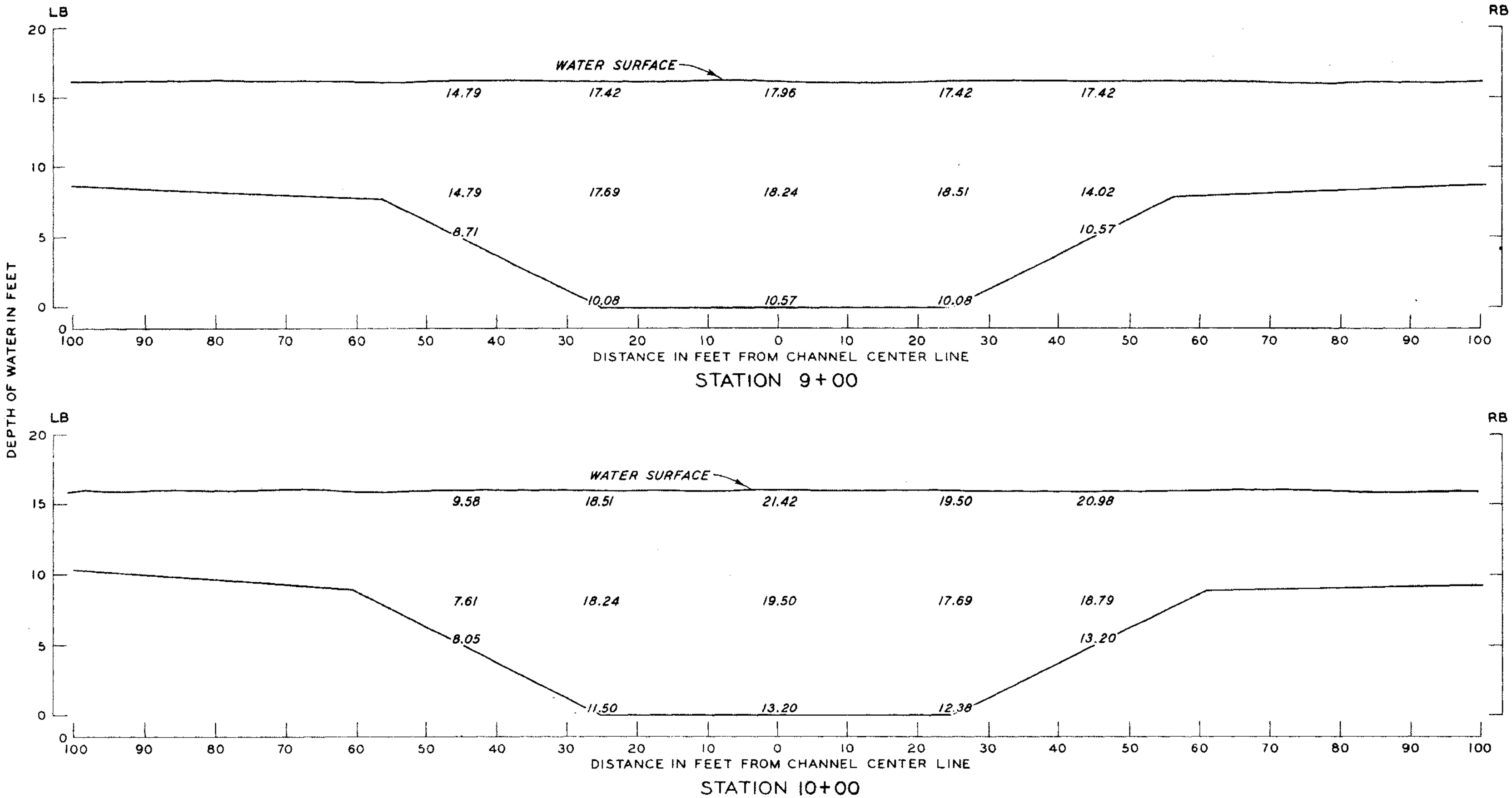



NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 20,000 CFS
TAILWATER ELEV 15.4 FT MSL
STATIONS 11+15 AND 11+70

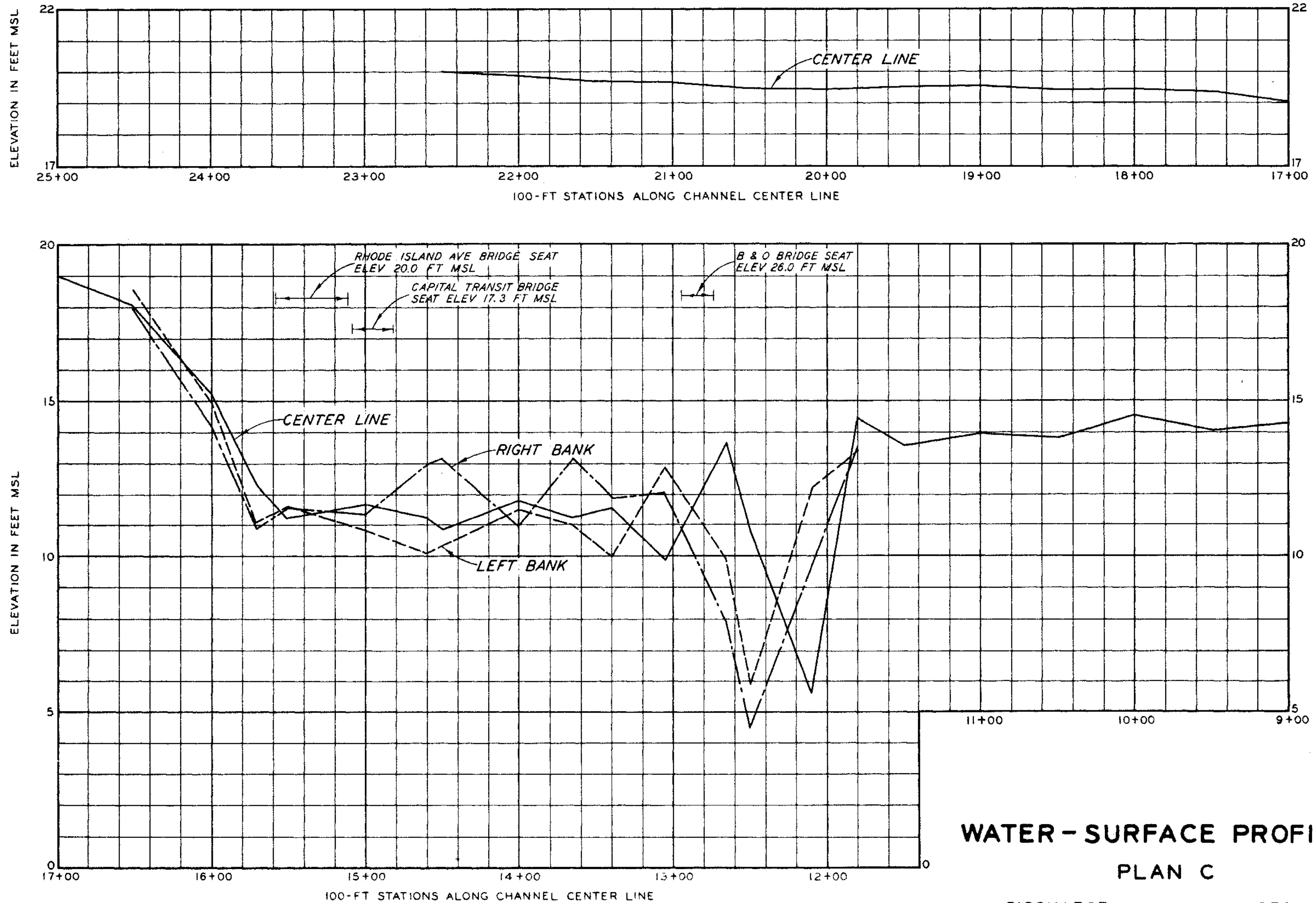



NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

## VELOCITY OBSERVATIONS

PLAN C

DISCHARGE 20,000 CFS
TAILWATER ELEV 15.4 FT MSL
STATIONS 9+00 AND 10+00

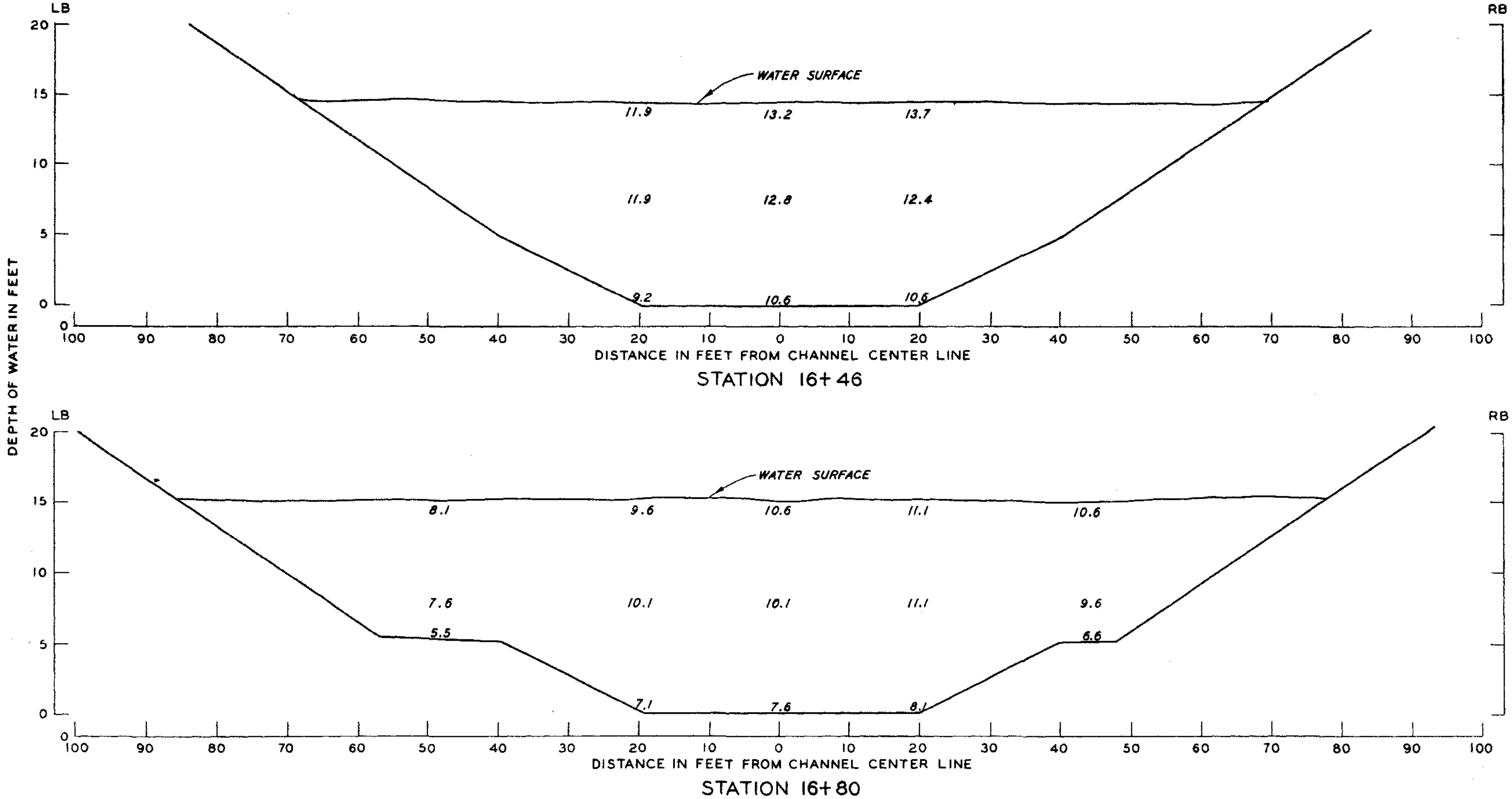



# WATER – SURFACE PROFILES

## PLAN C

DISCHARGE 16,000 CFS
TAILWATER ELEV 14.1 FT MSL

PLATE 29



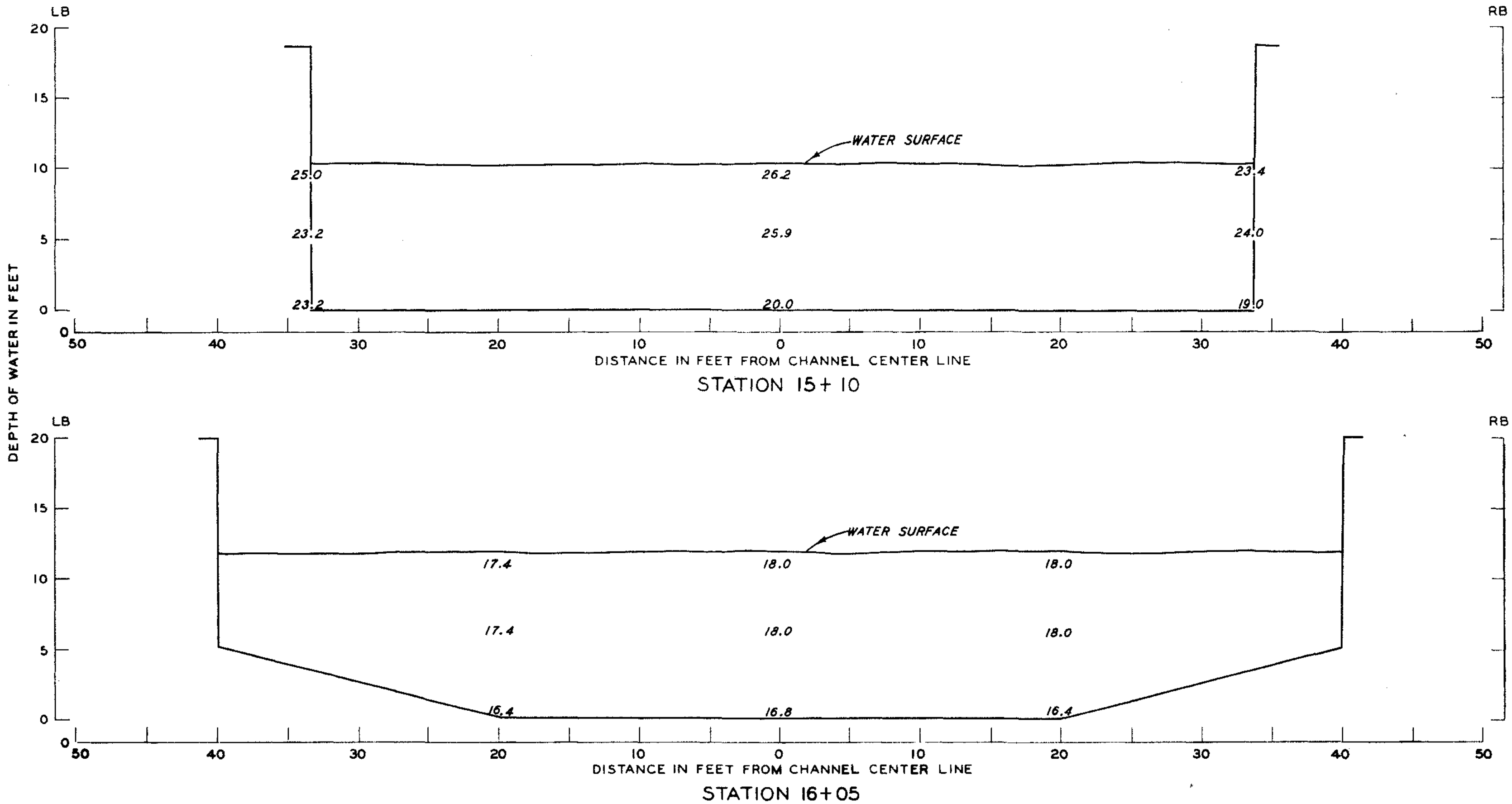

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 16,000 CFS
TAILWATER ELEV 14.1 FT MSL

STATIONS 16 + 46 AND 16+80



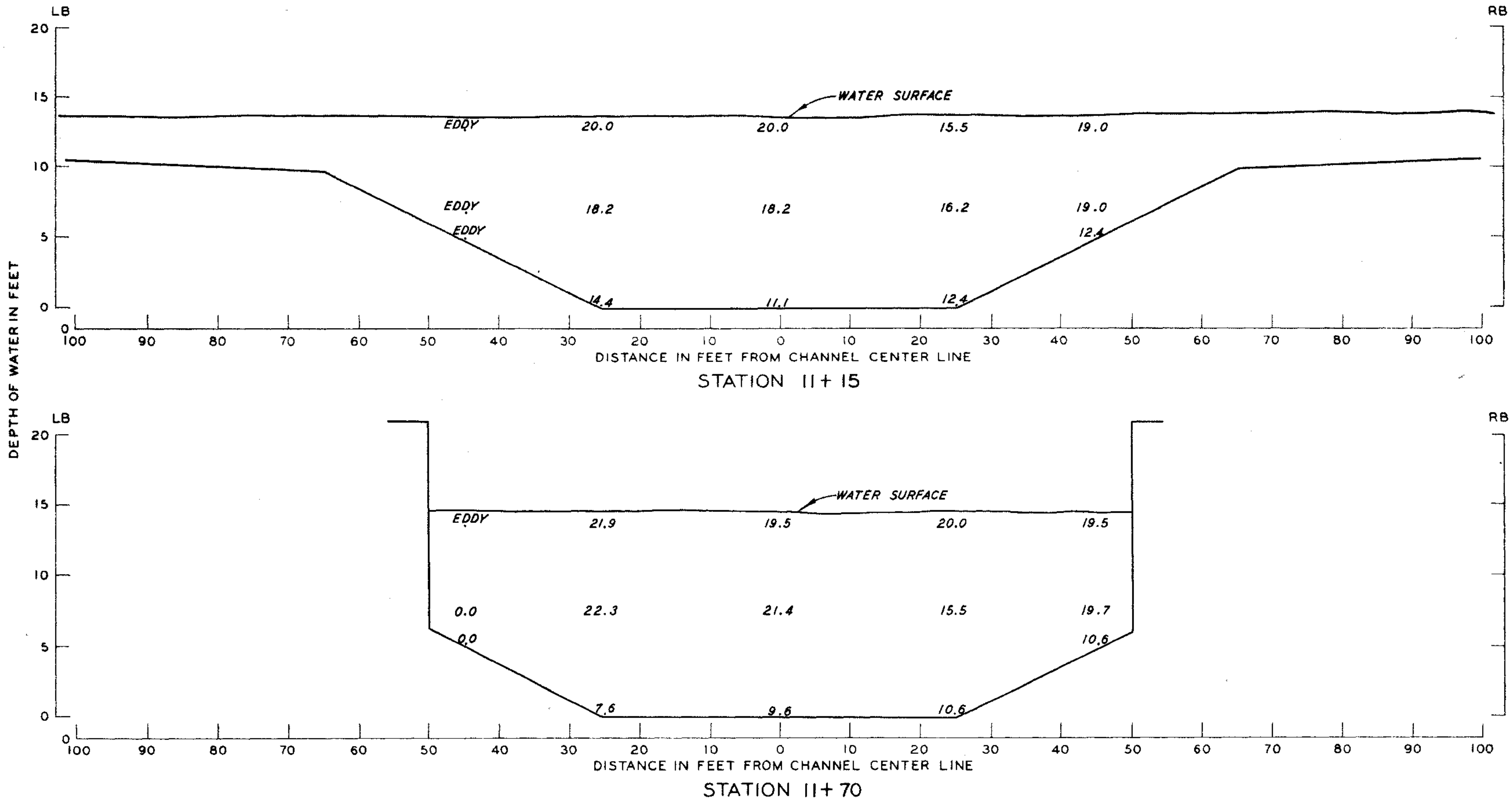

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 16,000 CFS
TAILWATER ELEV 14.1 FT MSL

STATIONS 15+10 AND 16+05




NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

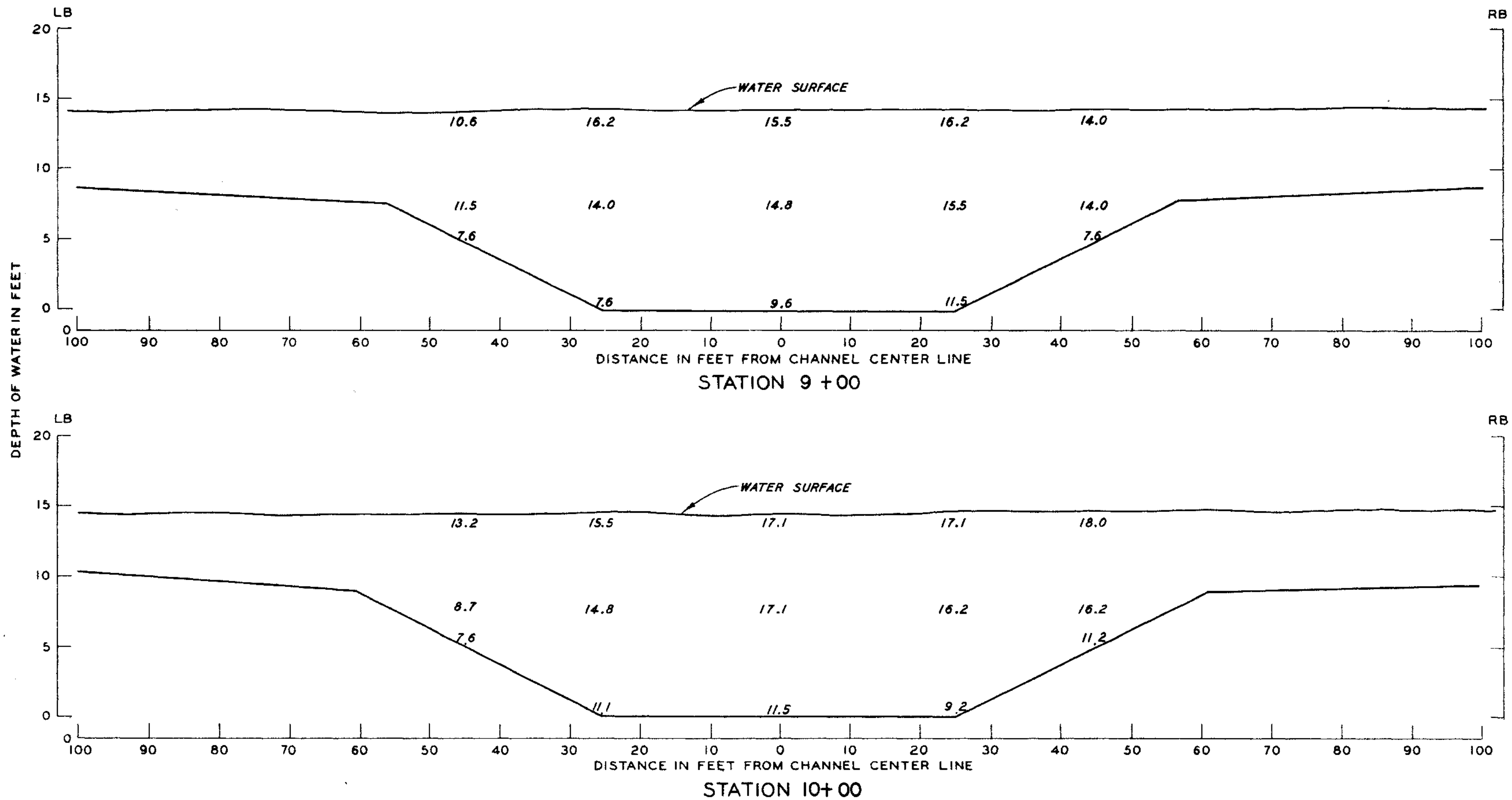
# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 16,000 CFS

TAILWATER ELEV 14.1 FT MSL

STATIONS 11+15 AND 11+70

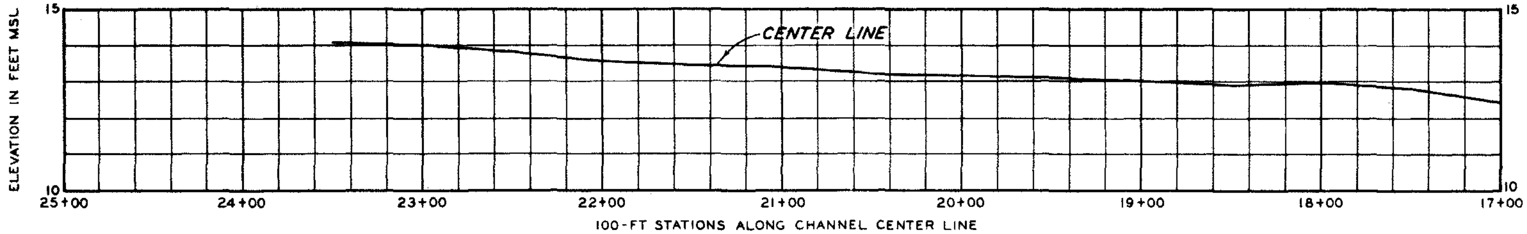


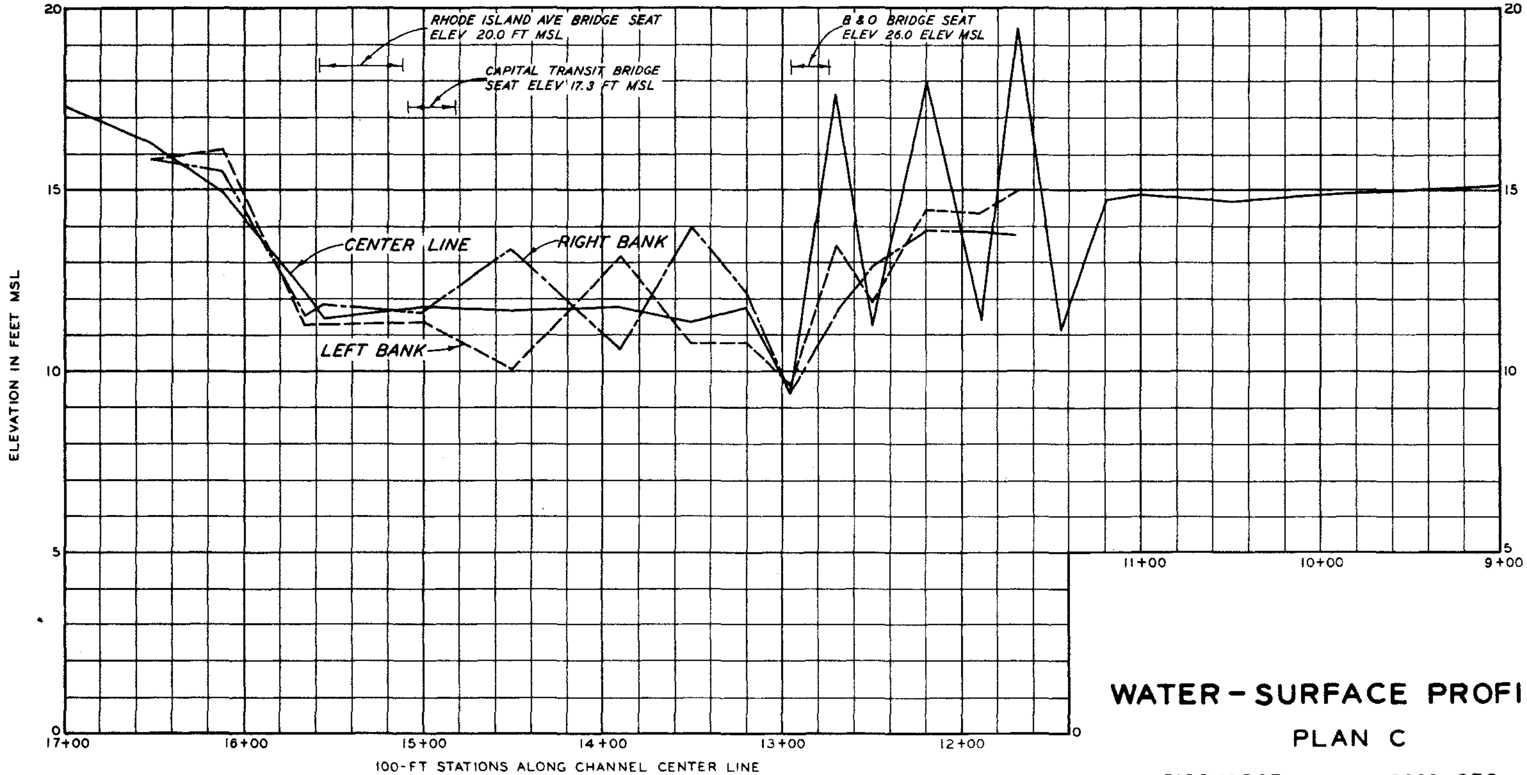

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 16,000 CFS
TAILWATER ELEV 14.1 FT MSL
STATIONS 9+00 AND 10+00



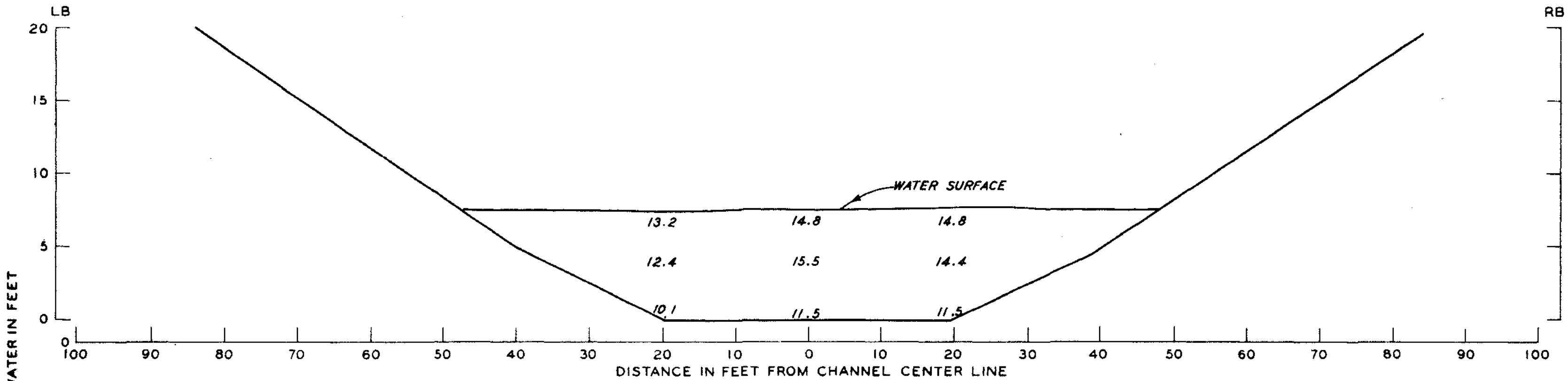




# WATER-SURFACE PROFILES

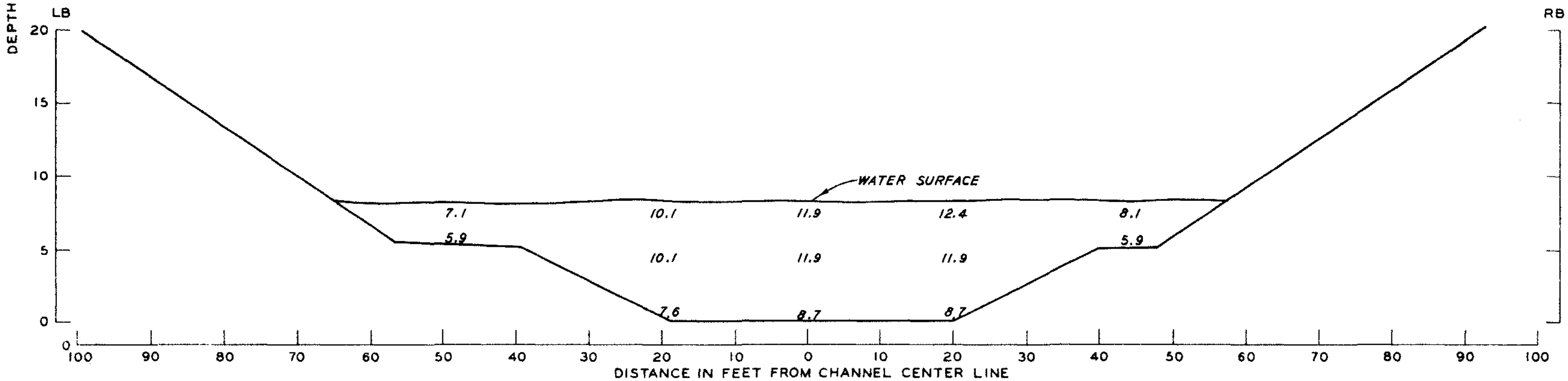
## PLAN C

DISCHARGE 8000 CFS

TAILWATER ELEV 10.0 FT MSL




STATION 16+46



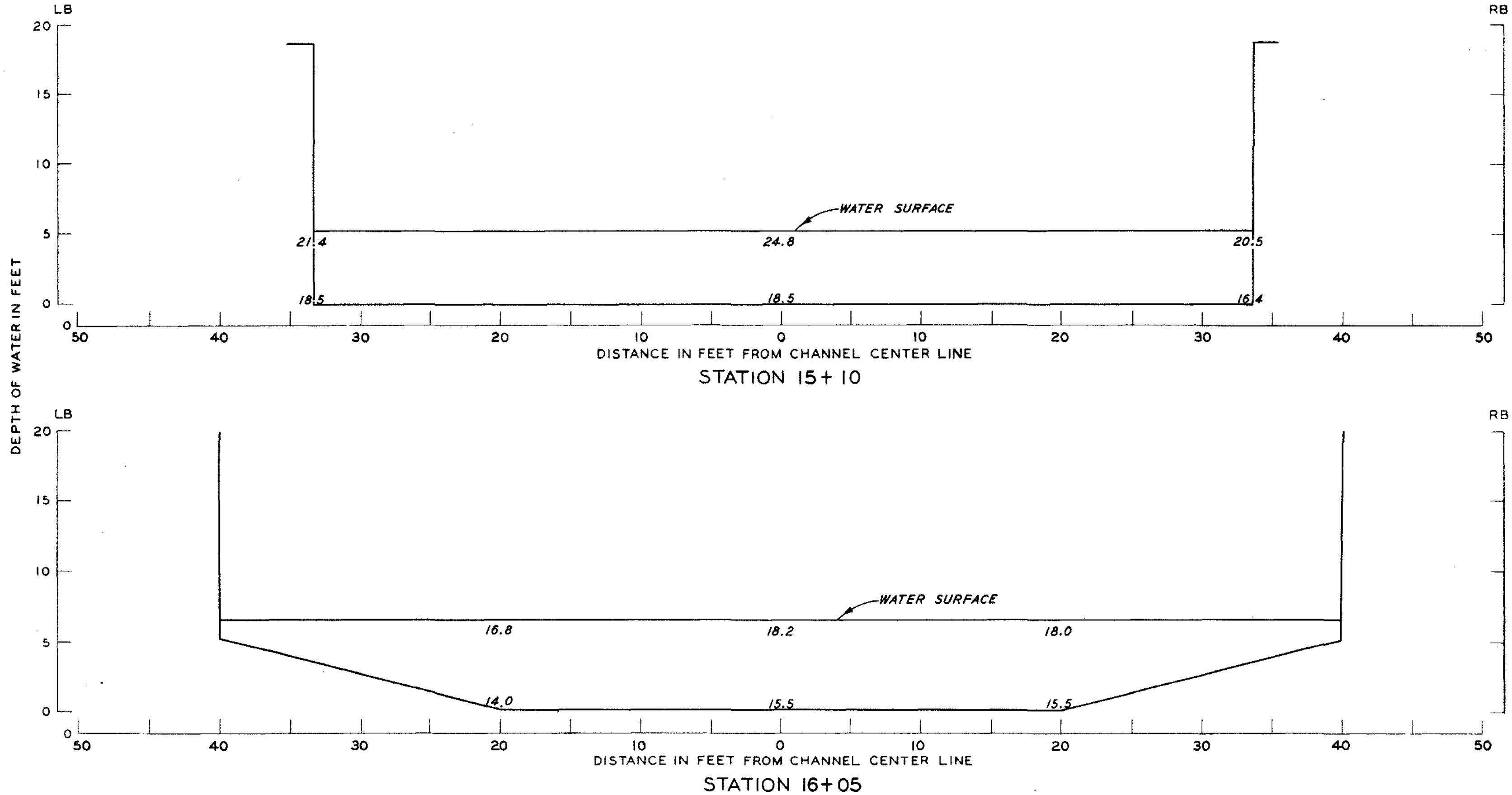

STATION 16+80

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 8000 CFS
TAILWATER ELEV 10.0 FT MSL
STATIONS 16+46 AND 16+80

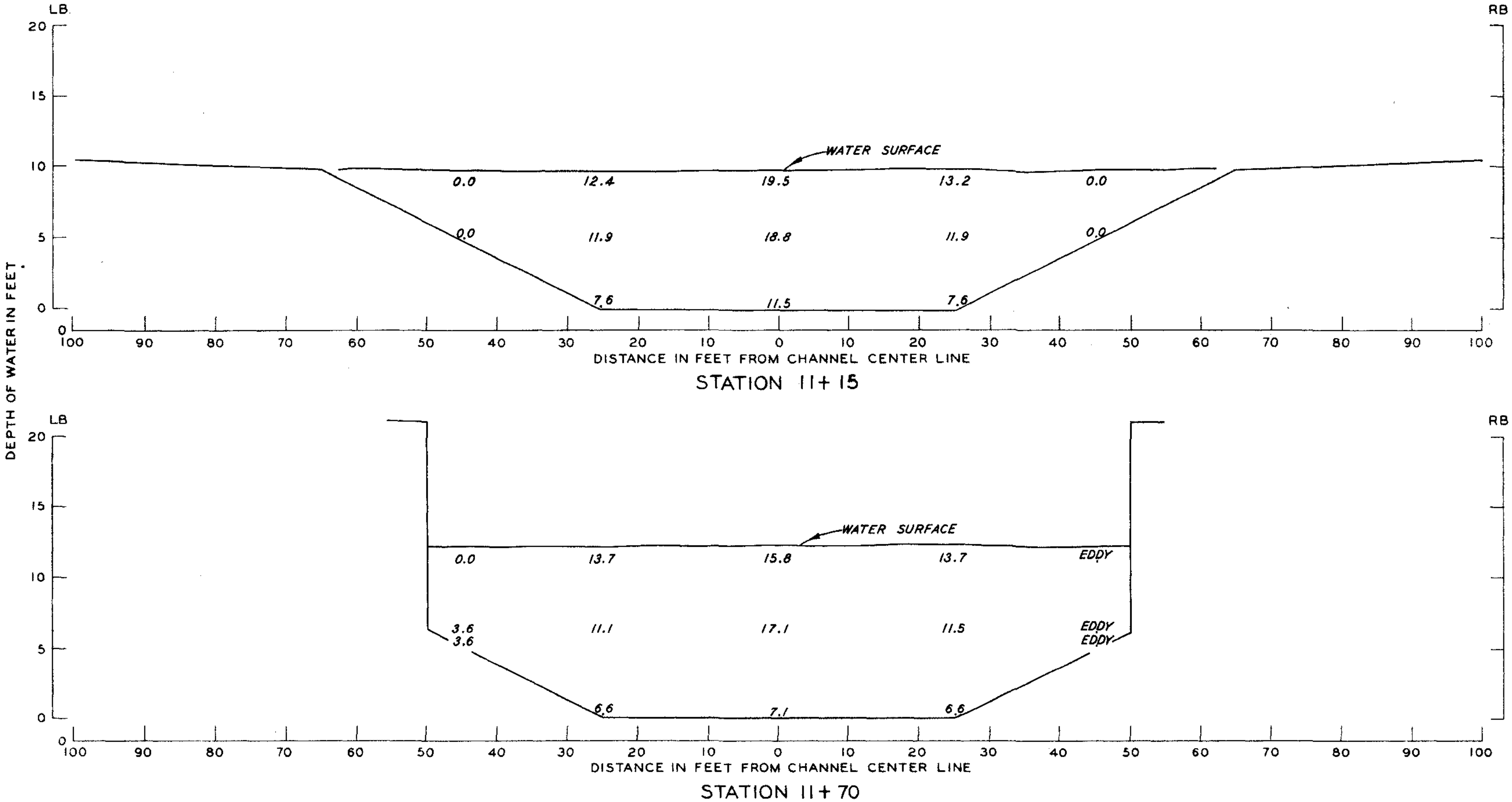



NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

# VELOCITY OBSERVATIONS

## PLAN C

DISCHARGE 8000 CFS
TAILWATER ELEV 10.0 FT MSL
STATIONS 15+10 AND 16+05

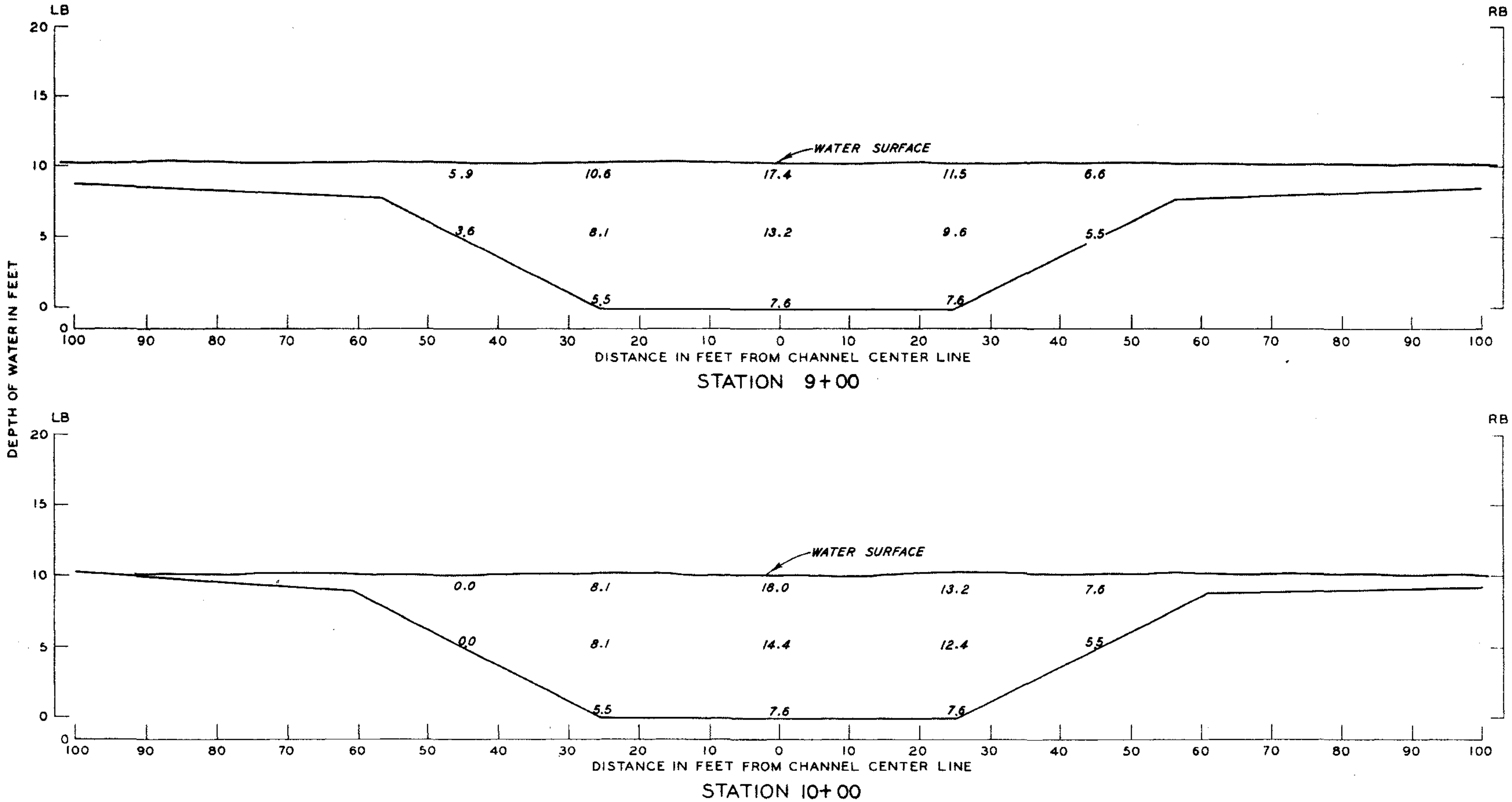



NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

## VELOCITY OBSERVATIONS

### PLAN C

DISCHARGE 8000 CFS
TAILWATER ELEV 10.0 FT MSL
STATIONS 11+15 AND 11+70



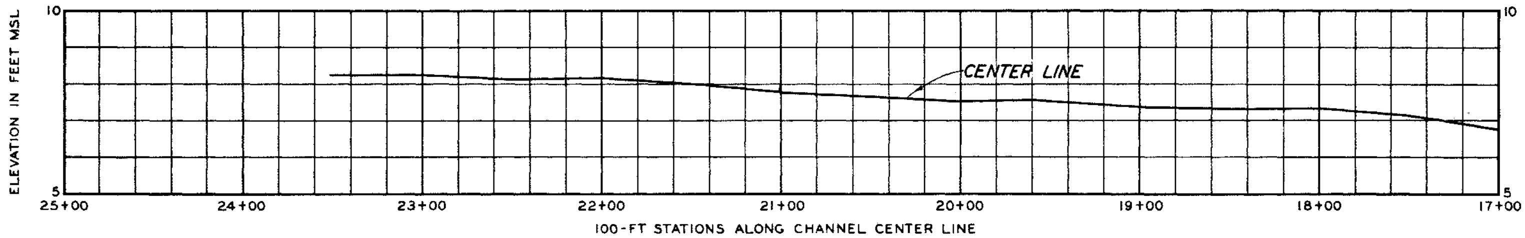

NOTE: VELOCITY IN FT PER SEC (PROTOTYPE).

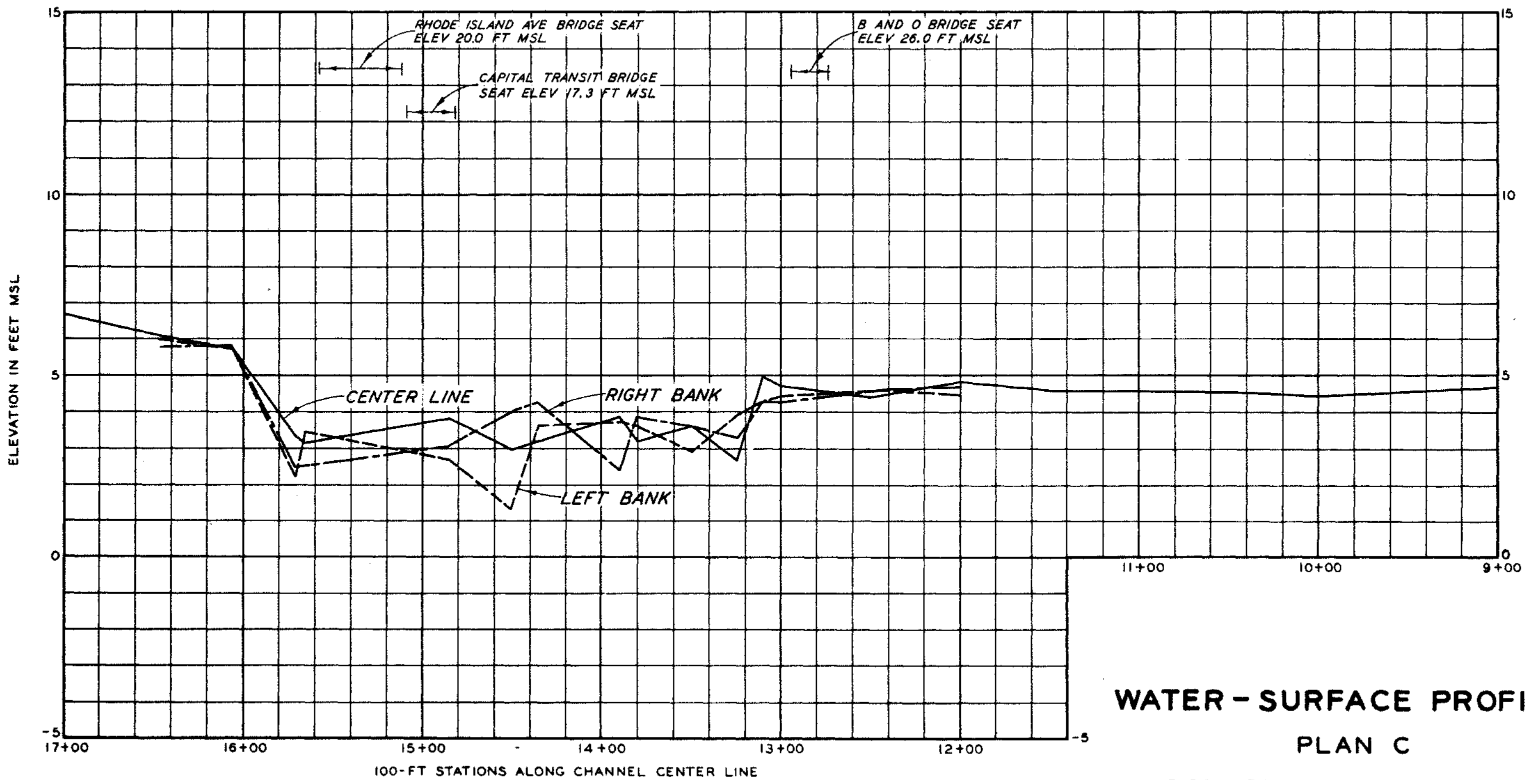
# VELOCITY OBSERVATIONS

## PLAN C

| | |
|---|---|
| DISCHARGE | 8000 CFS |
| TAILWATER ELEV | 10.0 FT MSL |

STATIONS 9+00 AND 10+00




**WATER-SURFACE PROFILES**

PLAN C

DISCHARGE 2000 CFS

TAILWATER ELEV 4.0 FT MSL